# TRANSACTIONS
OF THE
# AMERICAN FISHERIES SOCIETY

1934

SIXTY-FOURTH ANNUAL MEETING
MONTREAL, CANADA
SEPTEMBER 12, 13 and 14, 1934

# TRANSACTIONS

OF THE

# American Fisheries Society

SIXTY-FOURTH ANNUAL MEETING
MONTREAL, CANADA
September 12, 13 and 14, 1934

Published Annually by the Society

Washington, D. C.

1934

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# THE AMERICAN FISHERIES SOCIETY

**Organized 1870** **Incorporated 1910**

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The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

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## OFFICERS FOR 1933-1934

*President*........Fred A. Westerman, Lansing, Mich.
*Vice-President*........E. L. Wickliff, Columbus, Ohio
*Secretary-Treasurer*........Seth Gordon, Washington, D. C.
*Librarian*........Eben W. Cobb, Hartford, Conn.

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*Protection and Legislation*........Guy Amsler, Little Rock, Ark.
*Angling*........W. J. Tucker, Austin, Texas

## OFFICERS FOR 1934-1935*

*President*........E. L. Wickliff, Columbus, Ohio
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*Secretary-Treasurer*........Seth Gordon, Washington, D. C.
*Librarian*........Eben W. Cobb, Hartford, Conn.

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*Protection and Legislation*........Guy Amsler, Little Rock, Arkansas
*Angling*........Talbott Denmead, Baltimore, Md.

*For street addresses see membership list.

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| | |
|---|---|
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| Thaddeus Surber | St. Paul, Minnesota |
| S. B. Locke | Chicago, Illinois |
| Sumner M. Cowden | Albany, New York |
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| | |
|---|---|
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| James Brown | Montpelier, Vermont |
| John L. Farley | San Francisco, California |
| Frederic C. Walcott | Norfolk, Connecticut |
| W. F. Thompson | Seattle, Washington |

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| | |
|---|---|
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| O. M. Deibler | Harrisburg, Pennsylvania |
| W. J. Tucker | Austin, Texas |
| Harry B. Hawes | Washington, D. C. |
| Wm. C. Adams | Albany, New York |
| T. H. Langlois | Columbus, Ohio |

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| | |
|---|---|
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| S. F. Hildebrand | Washington, D. C. |
| William J. K. Harkness | Toronto, Can. |
| John O. Snyder | Stanford University, Calif. |
| Walter H. Chute | Chicago, Ill. |
| A. H. Leim | St. Andrews, N. B., Can. |

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| | |
|---|---|
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| Seth Gordon | Washington, D. C. |
| George C. Embody | Ithaca, N. Y. |
| Lee Miles | Little Rock, Ark. |
| Raymond J. Kenney | Boston, Mass. |
| George C. Warren, Jr. | Summit, N. J. |
| S. B. Locke | Chicago, Ill. |
| I. T. Bode | Des Moines, Iowa |
| M. F. Corrigan | McMinnville, Oregon |
| Charles E. Jackson | Washington, D. C. |
| John Van Oosten | Ann Arbor, Mich. |
| William J. K. Harkness | Toronto, Canada |
| John L. Farley | San Francisco, Calif. |
| William J. Tucker | Austin, Texas |
| James A. Rodd | Ottawa, Canada |

### Committee on Pollution

| | |
|---|---|
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| Talbott Denmead, *Secretary* | Washington, D. C. |
| S. B. Locke | Chicago, Ill. |
| Seth Gordon | Washington, D. C. |
| Milton P. Adams | East Lansing, Mich. |
| M. M. Ellis | Columbia, Mo. |
| John Van Oosten | Ann Arbor, Mich. |
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| Carl D. Shoemaker | Washington, D. C. |
| Henry B. Ward | Urbana, Ill. |
| William F. Thompson | Seattle, Wash. |
| Raymond J. Kenney | Boston, Mass. |
| A. H. Wiebe | Austin, Tex. |
| Grover C. Ladner | Philadelphia, Pa. |
| J. A. Rodd | Ottawa, Canada |

## PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

| | | | |
|---|---|---|---|
| 1. | William Clift | 1870-1872 | New York, N. Y. |
| 2. | William Clift | 1872-1873 | Albany, N. Y. |
| 3. | William Clift | 1873-1874 | New York, N. Y. |
| 4. | Robert B. Roosevelt | 1874-1875 | New York, N. Y. |
| 5. | Robert B. Roosevelt | 1875-1876 | New York, N. Y. |
| 6. | Robert B. Roosevelt | 1876-1877* | New York, N. Y. |
| 7. | Robert B. Roosevelt | 1877-1878 | New York, N. Y. |
| 8. | Robert B. Roosevelt | 1878-1879 | New York, N. Y. |
| 9. | Robert B. Roosevelt | 1879-1880 | New York, N. Y. |
| 10. | Robert B. Roosevelt | 1880-1881 | New York, N. Y. |
| 11. | Robert B. Roosevelt | 1881-1882 | New York, N. Y. |
| 12. | George Shepard Page | 1882-1883 | New York, N. Y. |
| 13. | James Benkard | 1883-1884 | New York, N. Y. |
| 14. | Theodore Lyman | 1884-1885 | Washington, D. C. |
| 15. | Marshall McDonald | 1885-1886 | Washington, D. C. |
| 16. | W. M. Hudson | 1886-1887 | Chicago, Ill. |
| 17. | William L. May | 1887-1888 | Washington, D. C. |
| 18. | John Bissell | 1888-1889 | Detroit, Mich. |
| 19. | Eugene G. Blackford | 1889-1890 | Philadelphia, Pa. |
| 20. | Eugene G. Blackford | 1890-1891 | Put-in-Bay, Ohio |
| 21. | James A. Henshall | 1891-1892 | Washington, D. C. |
| 22. | Herschel Whitaker | 1892-1893 | New York, N. Y. |
| 23. | Henry C. Ford | 1893-1894 | Chicago, Ill. |
| 24. | William L. May | 1894-1895 | Philadelphia, Pa. |
| 25. | L. D. Huntington | 1895-1896 | New York, N. Y. |
| 26. | Herschel Whitaker | 1896-1897 | New York, N. Y. |
| 27. | William L. May | 1897-1898 | Detroit, Mich. |
| 28. | George F. Peabody | 1898-1899 | Omaha, Nebr. |
| 29. | John W. Titcomb | 1899-1900 | Niagara Falls, N. Y. |
| 30. | F. B. Dickerson | 1900-1901 | Woods Hole, Mass. |
| 31. | E. E. Bryant | 1901-1902 | Milwaukee, Wis. |
| 32. | George M. Bowers | 1902-1903 | Put-in-Bay, Ohio |
| 33. | Frank N. Clark | 1903-1904 | Woods Hole, Mass. |
| 34. | Henry T. Root | 1904-1905 | Atlantic City, N. J. |

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

| | | | |
|---|---|---|---|
| 35. | C. D. Joslyn | 1905-1906 | White Sulphur Springs, W.Va. |
| 36. | E. A. Birge | 1906-1907 | Grand Rapids, Mich. |
| 37. | Hugh M. Smith | 1907-1908 | Erie, Pa. |
| 38. | Tarleton H. Bean | 1908-1909 | Washington, D. C. |
| 39. | Seymour Bower | 1909-1910 | Toledo, Ohio |
| 40. | William E. Meehan | 1910-1911 | New York, N. Y. |
| 41. | S. F. Fullerton | 1911-1912 | St. Louis, Mo. |
| 42. | Charles H. Townsend | 1912-1913 | Denver, Colo. |
| 43. | Henry B. Ward | 1913-1914 | Boston, Mass. |
| 44. | Daniel B. Fearing | 1914-1915 | Washington, D. C. |
| 45. | Jacob Reighard | 1915-1916 | San Francisco, Calif. |
| 46. | George W. Field | 1916-1917 | New Orleans, La. |
| 47. | Henry O'Malley | 1917-1918 | St. Paul, Minn. |
| 48. | M. L. Alexander | 1918-1919 | New York, N. Y. |
| 49. | Carlos Avery | 1919-1920 | Louisville, Ky. |
| 50. | Nathan R. Buller | 1920-1921 | Ottawa, Canada |
| 51. | William E. Barber | 1921-1922 | Allentown, Pa. |
| 52. | Glen C. Leach | 1922-1923 | Madison, Wis. |
| 53. | George C. Embody | 1923-1924 | St. Louis, Mo. |
| 54. | Eben W. Cobb | 1924-1925 | Quebec, Canada |
| 55. | Charles O. Hayford | 1925-1926 | Denver, Colo. |
| 56. | John W. Titcomb | 1926-1927 | Mobile, Ala. |
| 57. | Emmeline Moore | 1927-1928 | Hartford, Conn. |
| 58. | C. F. Culler | 1928-1929 | Seattle, Wash. |
| 59. | David L. Belding | 1929-1930 | Minneapolis, Minn. |
| 60. | E. Lee LeCompte | 1930-1931 | Toronto, Canada |
| 61. | James A. Rodd | 1931-1932 | Hot Springs, Arkansas |
| 62. | H. S. Davis | 1932-1933 | Baltimore, Md. |
| 63. | Fred A. Westerman | 1933-1934 | Columbus, Ohio |
| 64. | E. L. Wickliff | 1934-1935 | Montreal, Canada |

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# BUSINESS SESSIONS

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# TRANSACTIONS

OF THE

## 64th Annual Meeting of the

# AMERICAN FISHERIES SOCIETY

## MONTREAL, CANADA

### September 12, 13 and 14, 1934

FRED A. WESTERMAN, *Presiding*

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# REPORTS OF OFFICERS

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## REPORT OF THE SECRETARY-TREASURER

For the year 1933-34

SETH GORDON

I am pleased to report that during the past year the Society has more than held its own, which is something that not every organization of this kind can report today.

We have had applications for seventy-two new active members, five state members, one dealer membership, and one club membership, a total of seventy-nine. We have been compelled to drop for non-payment of dues thirty-five former active members, one state member, one club member, and one dealer member, a total of thirty-eight. We also had the following resignations: active members, seven; club members, one; dealer members, one; a total of nine. We lost from our ranks by death during the fiscal year, July 1, 1933 to June 30, 1934, a total of seven of which we have record, a total loss of fifty-four, leaving the Society twenty-five members ahead.

Since July first, through the good offices of our friends in both the United States and Canada, and especially the Canadian members, we have had more than fifty applications for membership. I have a number of these here for formal presentation this morning, which came in recently; the rest of them were accepted by proper committee action. Several additional members passed away recently.

There are still too many fish culturists, all of whom should be deeply interested in the work of this Society, who are not members of the Society. That is due, I think, largely to the fact that they have not been impressed with the importance of becoming members, also because too few of the states and provinces follow the example of Minnesota, which enrolls each of its fish hatchery superintendents, and pays the fee for them. In this way the Transactions of the Society automatically become a part of the library at each

hatchery and there is soon built up a reference library to which the superintendent of every hatchery may turn for guidance. This is of more importance than many of the other tools and equipment ordinarily bought.

Where for fiscal reasons it is not possible to enroll fish culturists in this way the only thing to do, of course, is to get the superintendents of hatcheries to enroll personally.

During the year a considerable number of scientific workers have been added to the rolls of the Society, which is a very encouraging sign.

Below I am submitting a statement of the finances for the fiscal year July 1, 1933 to June 30, 1934.

I should like to call attention to the fact that because of the larger size of our Transactions in 1933, consisting of 456 pages, with a great many cuts, as against 432 pages in 1932 with a considerably smaller number of cuts and diagrams, the 1933 volume cost us $1,453.47 as against $1,178.71 in 1932. The larger our programs are and the more cuts and illustrations we use, the greater will be the cost of printing.

Before the Transactions are placed in the hands of the printer we always get competitive bids from at least three printers, so that we are getting the lowest price we can possibly obtain for the kind of volume we are putting out. If you want to cheapen the volume by various processes—cheaper paper, cheaper printing, more condensation of material, smaller type instead of ten or twelve point type,—you can do that. But I would strongly recommend against it if you want to maintain the appearance and value of the recent volumes. I should like to have the members let us know what they recommend.

When you now get reprints or separates from the Transactions you are proud to pass them to friends who are interested in the same line of work, whereas if the printing were of a much cheaper grade, and smaller or less desirable type used, I doubt whether you would be interested in handing separates around to interested friends who do not receive the Transactions regularly.

## TREASURER'S REPORT

### July 1, 1933 to June 30, 1934

### General Fund

| | | | |
|---|---|---|---|
| **Receipts** | | | |
| Balance on hand July 1, 1933 | | | $ 122.31 |
| Annual Dues: | | | |
| Individuals and Libraries | | | |
| For the year | 1931-1932 | $ 9.00 | |
| | 1932-1933 | 66.01 | |
| | 1933-1934 | 836.85 | |
| | 1934-1935 | 27.00 | 938.86 |
| Clubs and Dealers | | | |
| For the year | 1931-1932 | 10.00 | |
| | 1932-1933 | 25.00 | |
| | 1933-1934 | 92.50 | 127.50 |

| | | |
|---|---|---|
| State Memberships | | |
| For the year 1932-1933 | 10.00 | |
| 1933-1934 | 190.00 | |
| 1934-1935 | 10.00 | 210.00 |
| Sale of Transactions | | 177.90 |
| Sale of Separates | | |
| 1931 Transactions | 16.50 | |
| 1932 Transactions | 246.14 | |
| 1933 Transactions | 35.75 | 298.39 |
| Sale of Index | | 13.00 |
| Miscellaneous: | | |
| Refund on postage | 12.00 | |
| Refund American Game Conference Transactions | .50 | 12.50 |
| Total Receipts | | $1,900.46 |

DISBURSEMENTS

| | | |
|---|---|---|
| Transactions, 1933, Vol. 63 | | |
| Reporting | $ 166.50 | |
| Cuts | 193.03 | |
| Indexing | 76.44 | |
| Additional proofreading assistance | 25.00 | 460.97 |
| Postage | | |
| Librarian's office | 5.00 | |
| Secretary's office | 113.70 | 118.70 |
| Rental safe deposit box | | 5.50 |
| Office supplies | | 13.59 |
| Stationery and printing | | 62.95 |
| Express | | 9.67 |
| Clerical and secretarial expenses | | |
| American Game Association | 100.00 | |
| Ethel M. Quee | 150.00 | |
| Seth Gordon | 100.00 | 350.00 |
| Traveling and entertaining | | 10.79 |
| Premium on bond | | 5.00 |
| Miscellaneous | | 4.90 |
| Telephone | | .30 |
| Separates, 1932, vol. 62 | | 256.48 |
| Returned check, no funds | | 3.00 |
| Exchange on checks | | 2.60 |
| Tax on checks | | .56 |
| Total Disbursements | | $1,305.01 |
| Receipts General Fund | $1,900.46 | |
| Disbursements General Fund | 1,305.01 | |
| Balance on hand July 1, 1934 | | $ 595.45 |

## PERMANENT FUND

| | | |
|---|---|---|
| **Receipts** | | |
| Balance on hand July 1, 1933 | | $ 91.08 |
| Interest on savings account | $ 5.34 | |
| Interest on Title Guarantee & Trust Co. Certificates and N. Y. Title & Mortgage Certificates | 122.23 | |
| Dividends on Commonwealth Southern, pfd. | 58.50 | 186.07 |
| Total Receipts | | $ 277.15 |
| **Disbursements** | | |
| No disbursements | | |
| Receipts Permanent Fund | $ 277.15 | |
| Disbursements | —— | |
| Balance on hand July 1, 1934 | | $ 277.15 |
| Par value Certificates Title Guarantee & Trust Co. | | $4,000.00 |
| Par value 10 shares Commonwealth & Southern pfd. @ $100 each | | 1,000.00 |
| Par value Certificates of N. Y. Title & Mortgage Co. | | 1,000.00 |
| Total | | $6,000.00* |

*The market value of Certificates of Guarantee and Trust Co. and N. Y. Title and Mortgage Co. during the past year has been considerably below par, but since there is no open market there is no established cash value available. The cash value of the 10 shares of Commonwealth & Southern pfd., par value $100., as of June 30, 1934, was $465.

For the further information of the members of the Society, I have prepared a brief supplemental report covering the period of July 1 to September 4, which shows that during that period we had receipts of $1,236.73, and expenditures of $1,284.88, with a balance on hand in the general treasury of $547.30. During this same period we also received 43 individual applications for membership.

The report of the Secretary-Treasurer was received and referred to the Auditing Committee. Upon the approval of the committee it was later accepted as submitted.

## REPORT OF LIBRARIAN

EBEN W. COBB

During the last year the only thing to report is that all letters have been answered as regards the volumes on hand and the price of same and all letters requesting information of any nature.

All volumes are kept in the vaults at the State Office Building where they are in good condition.

Transactions American Fisheries Society on hand Sept. 1st, 1934, not including office copies:

| | | | |
|---|---|---|---|
| 1876 | 3 | 1918 | 39 |
| 1895 | 11 | 1919 | 144 |
| 1896 | 23 | 1920 | 139 |
| 1897 | 41 | 1921 | 81 |
| 1898 | 43 | 1922 | 74 |
| 1901 | 2 | 1923 | 67 |
| 1904 | 32 | 1924 | 186 |
| 1906 | 121 | 1925 | 38 |
| 1907 | 35 | 1926 | 95 |
| 1908 | 126 | 1927 | 27 |
| 1909 | 95 | 1928 | 169 |
| 1910 | 93 | 1929 | 204 |
| 1911 | 82 | 1930 | 191 |
| 1912 | 150 | 1931 | 228 |
| 1913 | 191 | 1932 | 163 |
| 1914 | 19 | 1933 | 130 |
| 1915 | 20 | | |
| 1916 | 9 | Index Cloth | 647 |
| 1917 | 63 | Index paper | 217 |

THE SECRETARY: On the back of the Transactions for last year we gave a list of missing numbers of the Transactions, and some of them are still missing. I hope some of the members may find among their friends those who would be willing to help complete the Society's files.

THE PRESIDENT: The Society owes a debt of gratitude not only to Mr. Cobb but to the State of Connecticut for the provision they have made for the Transactions, space for them being provided, I understand, in fireproof vaults in the state capitol building at Hartford.

# REPORTS OF STANDING COMMITTEES

## REPORT OF MEETING OF THE COUNCIL OF THE SOCIETY

The Council of the American Fisheries Society met at the Hotel Windsor, Montreal, Canada, on September 11, 1934, at 9:30 P. M. Members of the Council present were: Fred A. Westerman, president; E. L. Wickliff, vice-president; Seth Gordon, secretary-treasurer; and Messrs. Eugene Surber and Sumner M. Cowden, of the Executive Committee. Also present by invitation were B. O. Webster, vice-president of the Division of Fish Culture; Guy Amsler, vice-president of the Division of Protection and Legislation; and G. C. Embody, former president of the Society.

The status of the Society's affairs, and the program for the forthcoming annual meeting were discussed, and various matters were acted upon as follows:

It was agreed that the annual index of the Transactions shall contain the scientific names of fishes for the use of scientific workers, and to expedite publication of a consolidated index at some later date.

To enable the officers of the Society, and the local committees, to prepare the best possible programs, and to expedite presentation of papers to allow more time for open discussions, it was decided:

1. That hereafter titles of papers shall be submitted to the Secretary at least ten (10) days in advance of the opening session;
2. That authors of papers shall be requested to present the highlights of their papers within ten (10) minutes, if at all possible; the papers in full, with summary of conclusions at the end, to be printed in the Transactions; and
3. That not to exceed two (2) papers shall be presented by any one member at any annual meeting.

It was decided that the present Committee on Abstracts of Foreign Fisheries Literature, consisting of Messrs. H. S. Davis and J. A. Rodd, be continued for another year with the same appropriation as granted last year; also that members who are conversant with such foreign literature be requested to cooperate with the Committee in the preparation of abstracts for publication in the Transactions.

There being no further business, the Council adjourned at 11:30 P. M.

Seth Gordon, *Secretary,*

## REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

J. A. Rodd, *Chairman*

The report of the Committee on Foreign Relations is largely a repetition of the report submitted last year. The treaties and agreements referred to then are still in effect. At the present time there is no fishery question of major importance in the boundary waters of Canada and the United States on which action has not been taken. In the case of various questions agreement has already been

reached. In other cases international investigations have been made or are now in progress.

The Pelagic Sealing Treaty of July 7th, 1911, entered into by Great Britain, the United States, Japan, and Russia, is an outstanding instance of international achievement. As a result of this treaty the fur seal herd that breeds on the Pribilof Islands but had become almost negligible from a commercial point of view in 1910 has been increased to approximately 1,000,000 animals, permitting an annual take of over 50,000 skins of surplus males.

The convention between the United States and Canada for the preservation of the valuable halibut fishery of the eastern portion of the north Pacific Ocean promises results equally as satisfactory as those brought by the sealing treaty. Under the original convention, ratified on October 21st, 1924, the International Fisheries Commission, or Pacific Halibut Commission, was set up, and under the later halibut treaty of May 9th, 1930, the commissioners were empowered—subject to the approval of the President of the United States and the Governor-General of Canada—to make regulations governing the fishery. The eighth report of the commission has recently been issued, and the following extracts from it indicate the trend of the investigations and the gratifying progress which has been made:

> The Commission, through its scientific staff, has studied where and how the halibut live, the ways in which they are fished, and the effect of this fishing upon the supply of fish. By its biological studies it has shown the existence of distinct stocks of halibut inhabiting different banks, growing at different rates, and having each its own physical characteristics. And by remarkably accurate statistics it has followed from year to year, in the case of each stock, the intensity of the fishery and the yield therefrom, showing the dangerous depletion that had gone on unchecked until 1930 and which called into existence the treaty under which the Commission now operates.
>
> So accurate for each stock has been the determination of the amount of gear "run" each year and so carefully studied the effect of the varying fishery upon the yield and supply that the Commission is in a position to determine in advance the effect of any given intensity, to a degree not equalled in any other fishery it has knowledge of.
>
> * * * *
>
> On southern grounds the increase has been 50 per cent in 1933 over that of 1930 and there has been a further increase in 1934. The lessened fishery has nevertheless given the fleet as large a yield each year as in 1930 and the Commission has reason to believe that the production of spawn has increased accordingly.
>
> * * * *

During the last forty years efforts have been made on several occasions to find means through an international agreement for the rehabilitation of the sockeye salmon run of the Fraser river and Puget Sound, which concerns both Canada and the United States. A Treaty entered into by the two countries on May 26th, 1930, was approved by the Parliament of Canada but awaits similar action by the United States Senate.

The International Pacific Salmon Federation, composed of representatives of fisheries departments of the federal governments of the United States and of Canada, and of each of the states of California, Oregon, Washington, the

Province of British Columbia and the Territory of Alaska, correlates the results of investigations in regard to Pacific salmon, and avoids unprofitable duplication of effort.

The Great Lakes Conservation Council, composed of representatives from the Department of Fisheries, Ottawa, the Bureau of Fisheries, Washington, D. C., the Province of Ontario and each of the states interested in the fisheries of the Great Lakes, has held several conferences to consider measures to counteract decline and restore these valuable fisheries to their former productiveness.

The Lake Erie Advisory Committee, an offspring of the Council, has contributed in a marked degree towards securing uniform regulations for Lake Erie. As a result of conferences held in Buffalo in 1931 and in Toronto in 1932 an agreement has been reached by the States of New York, Pennsylvania, Ohio and Michigan and the Province of Ontario in regard to certain questions, such as the abolition of the bull-net, affecting the fisheries of Lake Erie.

The pike-perch or dore fishery of Missisquoi Bay and Lake Champlain is also the subject of an investigation by an International Fact-Finding Commission appointed by Canada and the United States.

The International Commission appointed by the two countries concerned to investigate the possible effects which proposed power dams across Passamaquoddy Bay would have on the fisheries of that region has submitted its report.

The North American Council on Fishery Investigations, an international body composed of representatives from Canada, the United States, Newfoundland and France, which was established in 1920, meets this year in Halifax, Nova Scotia. It usually meets in alternate years in the United States and in Canada. This Council coordinates fisheries investigations in the western north Atlantic, correlates the results thereof and facilitates the exchange of scientific information amongst the countries concerned. The review of the mackerel fishery off the east coast of North America recently prepared for the North American Council by Messrs. Oscar E. Sette of the United States Bureau of Fisheries and Doctor A. W. H. Needler of the Biological Board of Canada, is an instance of cordial foreign relations.

Your Committee urges that this Society continue to support to the best of its ability in the future as it has in the past the solving of all these problems by international agreement.

### *Discussion*

Mr. Erling Swenson (Minnesota): May I ask Mr. Rodd a question? We are interested in these international boundary questions. We have numberless lakes along the northern boundary between Minnesota and Ontario. We also have the question of Lake Superior. I would like to ask the chairman of this committee whether in the past the negotiations affecting these waters have been between each state in the Union and the corresponding province in Canada, or has the federal government intervened to any extent by negotiating with the Dominion in the matter of regulations? It seems to me it is important to know who has the power and who has proceeded with the negotiations in the matter of any agreement between Canada and the United States and between the

various provinces of Canada and the states of the Union. It seems to me that we ought to carry forward some more comprehensive plan as between Canada and the United States with respect to fishing in international waters.

MR. RODD: In the matters to which I have referred, the pelagic sealing treaty and the Pacific salmon treaty, the negotiations have been carried on between the federal governments of the two countries.

MR. SWENSON: Did the state of Washington take any part in the negotiations?

MR. RODD: The direct negotiations were between the two federal governments, but the state and the province concerned were fully represented on the Commission. In the case of the halibut treaty, the negotiations were carried on between the two federal governments. The interests concerned were fully represented; they were consultd from time to time and the negotiations were carried on in full agreement with the halibut fishing interests. With regard to the Great Lakes Conservation Council, if I remember correctly, the first conference was called by the governor of Michigan. Representatives from both federal governments were at this conference. Then an offspring of that Great Lakes Conservation Council was the Lake Erie Advisory Committee, which I believe has been largely instrumental in securing uniform regulations for the waters and fisheries of Lake Erie. That agreement is between the states concerned and the province of Ontario. It is a matter of agreement between those authorities. In regard to lake Ontario, the agreement there has been between the state of New York and the province of Ontario. In the case of Passamaquoddy bay, the inquiries have been made and financed by the two federal governments. As to the North American Council of Fisheries Research that, of course, was a federal government matter. It will be seen, therefore, that where the interests concerned are entirely or very largely local, the negotiations have been carried on between the state and the province concerned. On the three different occasions that commissions were appointed by the two federal governments to inquire into all questions relating to the fisheries in the boundary waters of the two countries, those were federal commissions. The commission of 1908 and that of 1918 submitted a code of recommendations covering the fisheries from the Atlantic to the Pacific.

## REPORT OF THE COMMITTEE ON RELATIONS WITH FEDERAL, PROVINCIAL, AND STATE GOVERNMENTS

FRANK T. BELL, *Chairman*

Your committee welcomes this opportunity to report to this Society, in convention assembled, the part the governmental fisheries agencies have been privileged to play in the phenomenal and unprecedented advances conservation has made since last we met. These forces, ever mindful of their obligations as administrators, sustained by the tax-paying public, have genuinely endeavored to be faithful to that stewardship, and now share with those public-spirited conservationists, in this Society and in kindred organizations, inspired solely by the burning zeal to see our continent's wildlife redeemed and restored, the supreme thrill and satisfaction of seeing definite accomplishments toward that goal.

Our distinguished host, the Province of Quebec, whose generous hospitality of these days will long remain in our memories, has conveyed to us the gratifying report that their fisheries conservation program has been carried on undiminished, and it is evident that this reflects the general prevailing conditions throughout the provinces. Without the fine spirit of cooperation which has always existed between the provincial governments and the states, the comprehensive conservation program could not have been undertaken with any hope of ultimate achievement.

In April of this year, the U. S. Commissioner of Fisheries formed The National Planning Council of Commercial and Game Fish Commissioners as an operative agency to coordinate the fisheries forces of the Federal Government with those of the several states. This organization has formulated a national cooperative policy, and its formidable program embraces Federal and State cooperation in fish propagation and distribution, stream surveys and improvements, marine and fresh water fisheries investigations, soil erosion and reforestation work, pollution plans, statistical and scientific studies, and in methods of aiding the anglers and private conservation organizations. This will provide a medium through which the government and state officials can work together, rather than independently of each other, and thus eliminate misunderstanding, duplication of programs, and overlapping of efforts.

Of prime interest to this Society, the phase of this program which promises to loom large in the conservation picture is the establishment of a game fish division, to supplement the black bass protection work. This enlarged division will be under the direct supervision of Talbott Denmead, widely and favorably known in all conservation circles. This division's principal function will be the promotion of closer relationship between the Federal Government and the public conservation agencies, endeavoring to more effectively advance their common purposes. Under the expert guidance of Mr. Denmead, whose membership and acquaintance in the various sportsmen's organizations and his knowledge of fisheries science eminently qualifies him for this important cooperative and contact work, this division holds much promise.

During the past year, few legislatures met and impending conservation reforms in the game laws of several states have been held in abeyance. However, commencing January, 1935, some 44 state legislatures will convene, and many desired improvements to unify our game fish laws is anticipated.

A healthy spirit of cooperation has been seen in interstate meetings in the past several months, which points to the fact the people, as well as the state and government officials, are coming to realize that pollution and kindred problems affecting our aquatic life can be solved only by unified attack. We find cities maintaining rearing ponds, in conjunction with the states.

A conspicuous and enheartening example of state and Federal cooperation may be found in the Great Lakes area. Michigan, for example, collects through its conservation department statistics vital to its commercial fishing in the Great Lakes, and the Bureau of Fisheries, through its laboratory facilities at the University of Michigan, compiles and reduces the same to practical uses. In other states, cooperative use of mutual facilities is reducing the cost of oper-

ations in the scientific field to both the Federal and state administrations.

The Commissioner has now adopted the policy of submitting fish applications from the various states to the officials of the states themselves before distributing the fish, thereby insuring that proper species will be placed in the streams, in accordance with the plans of the states for stocking their own waters.

Your committee has merely indicated to you the progress that has been made along the lines of closer Federal and state cooperation, not having mentioned the far-reaching conservation laws enacted by both the state and national legislative bodies, or the emergency relief projects benefitting our streams, rivers and lakes. It would be impossible adequately to do justice to the aggressive program now going forward. In this united advance, the importance of the part played by such organizations as the American Fisheries Society, in pioneering and fostering public sentiment to conservation's needs, cannot be overestimated, and this wholsome cooperation on the part of all the combined forces, both private and governmental, augers well for conservation's future.

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## COMMITTEE ON THE SCIENTIFIC NAMES OF FISHES

THE PRESIDENT: A committee, which was named a year ago, is working on the problem of adopting uniform common and scientific names of fishes, with Dr. Hubbs as chairman. We have not a report from that committee for presentation at this time, but that is also a very important matter, because there is a great deal of confusion among the several states and the provinces with regard to the common names of fishes. Many members of the Society and of the public at large are interested in this subject, and it is a task that the Society can well undertake and work through to a conclusion. I hope that when the Society meets next year the Committee on Common and Scientific Names of Fishes will have a report for us.

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## REPORT OF THE AMERICAN FISH POLICY COMMITTEE

E. L. WICKLIFF

At the 63rd Annual Meeting of the American Fisheries Society, President Fred A. Westerman was authorized, by resolution, to appoint a committee to cooperate with the American Game Conference, and other bodies in a position to give assistance, to draft an American Game-fish Policy and to make a progress report at this meeting.

During the Columbus session Mr. Seth Gordon, President of the American Game Association, presented a paper entitled, "Scientific Management—Our Future Fisheries Job," in which he pointed out the need for an American Game-Fish Policy.

On January 22, 1934, the Council of the American Fisheries Society held a joint meeting with the International Association of Game, Fish and Conserva-

tion Commissioners at the Pennsylvania Hotel in New York City and sponsored the American Fish Policy in cooperation with International, National and Regional groups.

On January 24, 1934, President Westerman read a paper at the American Game Conference entitled, "An American Fish Policy," in which he pointed out the basic importance of the biological, economic and social phases of our fisheries problems and suggested a more orderly course of fisheries management in the future.

Under date of May 29, 1934 I received a carbon copy of a letter sent by President Westerman to Secretary Gordon announcing the appointment of a committee to draft an American Fish Policy. Since then your Chairman has devoted considerable time and thought to this very important task and on August 16, 1934 sent a tentative outline for a proposed American Fish Policy to each of the fourteen members of the committee. To date, practically all of the members have responded with helpful suggestions and constructive criticisms. Letters were also mailed to several others interested in the policy and valuable comments were received.

After going over all of this material in some detail, the Committee offers the following suggestions for your consideration:

We realize that an American Fish Policy to be successful must have broad, general, elastic requirements with a working plan of activities and with statements of policy. At this time details cannot be laid down because of the complexity and diversity of the fisheries problems on the continent. We know that the proper procedure for a policy is not a matter of judgment, decision, oratory or debate, but is based upon cold biological facts. Unfortunately, in many cases, exact information is lacking and it may be hard for the administrator or the general public to understand that practical fish production cannot be compared with automobile production, because in fishes we are dealing with living things and know very little about them.

The Committee feels it should serve as a clearing house for improved methods of fish management and by proper educational procedure should sell these improvements, to those who should profit by using them.

At present there is considerable discussion about land management. This, we think, should include our aquatic resources because the control of soil erosion, reforestation development, drainage projects, grazing by cattle and sheep, farm dams and numerous other land projects are all interwoven in our big problem of water conservation, including water restoration. Those charged with land management should have men trained in water conservation to assist in directing their efforts to *hold* the water, because the five-year drought in parts of this country has proven we know how to divert the water and let it run off into the ocean, but apparently do not, in all projects, realize the importance of retaining it. The first requirement for all fishes is water and unless we have an adequate supply of suitable water our fish policy will *not* work.

Agriculture passed through all the stages from dirt farming to applied science and probably aquiculture must do the same to be successful. We have the co-

operation of the committee of eighteen members on Hydrobiology and Aquiculture of the National Research Council. We also have a copy of their report entitled "Cooperative Research in Aquiculture." Two members of the Fish Policy Committee are members of the Hydrobiologists Committee. The object of their work is to bring science and practice closer together and a cooperative method should be worked out with them in order to make this possible. Last night the committee met with the United States Fish Commissioner, Frank T. Bell, and unanimously approved the eight points in his National Fish Policy.

The Federal and Dominion Governments, the provinces, states, universities, experiment stations, sportsmen, commercial fishermen and general public should all be made a part of the cooperative project and to feel their importance in its operation. For instance, we need the industrial stream polluter in our program and should point out to him how the effluent from his factory interferes with our water conservation program and how he can control it. The immediate projects should be put across in an orderly program for the investigation, management and expansion of our fishery resources, including present and future needs.

Where we have an adequate supply of suitable water, the dominion, provincial, federal and state authorities should at once set up certain experimental fishery projects including fish propagation, proper stocking methods, control of pollution, stream and lake surveys and improvements, life history studies, creel census work, together with a broad educational program stressing fishes as crops. These problems are all self-explanatory and probably should be started before other projects that seem of lesser importance. The work, in many cases, could be done by qualified persons if they were at least "grub-staked" while doing it. Such men may be found in our universities, colleges and experiment stations.

While it is true that increase in knowledge has caused overproduction in certain kinds of farm crops, this same type of knowledge is needed for increasing our fish production and at this time the Committee does not think that overproduction is a problem in game fish propagation because of the large number of anglers ever ready to catch them. Fish or game management cannot be better than our knowledge of their natural requirements and even though the basic information is available we need *interpreters* for its practical application and *administrators* to put it into effect. Fish culturists should know the fundamentals of biology and biologists certainly need a practical course in fish culture.

At present, only a small part of our conservation activities are based upon experimental facts, but if we expect to make more rapid strides in the future than we have in the past a larger part of the budget must be spent for fact-finding and such workers should not be disturbed in their investigations or be burdened with administrative duties.

The final success of any fish policy depends largely upon the cooperation of the administrators, fish culturists and biologists and when all three talk the same language and utilize the facts of experimentation the fish policy will be a success.

# REPORTS OF VICE-PRESIDENTS OF DIVISIONS

## REPORT OF THE VICE-PRESIDENT OF THE DIVISION OF FISH CULTURE

B. O. WEBSTER

In its sixty-four years of existence the American Fisheries Society has seen the science of fish culture progress and overcome one after another of the one-time seemingly insurmountable obstacles. I do not intend to review or even summarize the many obstacles that have been overcome because many here are more familiar with them than I. But at the risk of being called too forward I do want to suggest that the last few years have seen appreciable advance into a field in which the fish culturists of North America have seemed to be remiss. I mean the application of fish culture in the field, a definite attempt to improve the habitat for the fish which we produce in our hatcheries, which heretofore we seem to have forgotten about when the fish were put in cans and removed from the hatchery.

A concentration of cultural efforts in the hatcheries has produced remarkable results. High efficiency attends the artificial propagation of fish. In certain species we have been able to hatch as high as ninety-five per cent of the eggs taken. Further, but still in the hatcheries or close to them, we have learned to rear the fish to a fingerling or even an adult size before being planted, but we have been alarmingly remiss in protecting our product after it has left our hands.

Happily, the last few years have seen a change in attitude. In most states and provinces there have been definite efforts to protect, restore, or improve the habitat of fish so that the product of the hatcheries will have a better chance of reaching maturity and reproducing naturally than in years past.

### WATER POLLUTION

Probably the greatest man-made obstacle to success in fish culture is water pollution. Commercial factories, agricultural processing plants, and municipalities have for generations been dumping their wastes into the streams, rivers and lakes of North America.

It is true that there have been a great number of cities that installed sewage disposal plants, just as it is true that there have been water pollution committees and research bodies studying the commercial waste problem. It is only in the last three or four years that much hope of a wholesale corrective program has been noticeable. Throughout the United States today, principally by make-work programs partly financed by the federal government and contributed to by local government, sewage disposal plants on a large scale have become possible for the first time.

An outstanding instance in pollution has been the condition caused in the Mississippi River between the twin cities, Minneapolis and St. Paul. These cities, each of them jealously guarding their self-assumed prerogatives at the expense of the other, have been polluting the river for miles below, and even beyond

the border of Minnesota, but now the cities are to be congratulated in that a joint sewage disposal plant is soon to be built. This should have a tremendously beneficial effect in improving the conditions of the upper Mississippi river, perhaps one of the greatest natural reservoirs and fish breeding grounds in North America.

As in this particular place, so it is throughout the country—more and more such plants are being constructed. I think that they might be called one of the benefits of the depression.

### Fishways

Unless it be water pollution, there is probably no other one factor which has done so much to deplete the numbers of game fish in American waters as the construction of innumerable dams across the rivers and streams of North America. Any obstruction in a river or stream which interferes with the migration of fish at spawning time has a most detrimental effect upon natural reproduction. If fish can not find the best spawning ground in the headwaters of rivers and streams, they must deposit their spawn under less favorable circumstances. Under the best of circumstances the number of eggs which ultimately produce mature fish is very low, and any lessening of the favorable circumstances practically results in no natural reproduction. This is the situation as it exists in water courses whose natural, uninterrupted flow has been obstructed by dams. Some people claim, particularly those who are interested in belittling the detrimental effects of dams on natural reproduction, that artificial propagation counteracts the injury done. But to those of us interested in fisheries work, artificial propagation is never and should never be considered as replacing natural reproduction. At the best, artificial reproduction only supplements natural reproduction.

The damage done to reproduction by dams in streams has been realized in varying degrees for many generations. But, except in coastal rivers where commercial species only are affected, little was ever done to counteract the damage until the last two or three decades. There are two reasons for this lack of attention in inland waterways: first, that it is only in the past few decades that the numbers of fish have seriously declined; and second, that it is in the last two decades that the numbers of dams across streams have increased so materially.

Almost without exception, the fishways which have been tried, and the few which have been found successful for commercial species, principally salmon in coastal rivers, have been of the fish wheel or fish ladder type. When the problem of providing means of access over dams for inland water species became acute, attempts were made to adapt the fish wheel or fish ladder type of fishway to these inland rivers. All such attempts failed.

Of the inland water species of fish, the only one which could adapt itself in any measure to the ladder type of fishway was the trout. But the power dams across inland water streams invariably were built on streams larger than trout streams, which meant that the trout were not affected as much as other species.

In the north central part of the United States, particularly in the lake states, this problem has become very important. The species of fish most directly concerned are the wall-eyed pike or pike perch, the pickerel or great northern pike,

the bass, and, in Wisconsin, the muskellunge and sturgeon. None of these species will use any type of fishway that requires leaping as does the fish ladder type; also, each of these species is entirely too cautious and wary to enter any fish wheel. Consequently up to the present time all attempts to provide access through or over dams for these fish have failed.

For more than 25 years the division of fisheries of the Wisconsin Conservation Commission has been experimenting with every type of fishway that seemed practicable. Intensive experimentation began in the three year period 1907-1908-1909. At this time experimental fishways were placed in dams across several Wisconsin rivers. Everything was done to make fair tests and to try to devise a successful fishway. A careful check was made and accurate records were kept of all fish that went through each of the fishways.

Late in the summer of 1930, another type of fishway came to the attention of the fisheries division. It was not of a fishway in operation, but rather of a plan or miniature designed, invented, and patented by Harry Barr, of Ironwood, Michigan. Steps were taken to make an experimental installation. Mr. Barr was so confident of its success that he paid the costs of installation himself.

Radically different in type from any fishway suggested before, the Barr type is really a fish lock or fish elevator. In operation it is quite similar to the locks which elevate boats from one level to another. As installed at the Rest Lake dam, the Barr fish lock consists of a large concrete box with a concrete floor, inlet and outlet valve, an egress tube and an automatic counter-balance tripping device. The outlet for water and inlet for fish is at the bottom of the river bed. Fish pass out from the fishway through a 24 inch pipe from the box to the lake.

I will not go into detail about the construction or operation of this fishway. Anyone interested can find out in detail by writing to the inventor or to me. Suffice it to say that in my opinion the Barr fishway is the most important contribution to inland water game fisheries program that has been made in the last twenty-five years. We in Wisconsin know that it works. During each of the past three years we have made a definite check of the number of fish that have gone through the Barr fishway in the Rest Lake dam. In all 6,571 fish have passed through the fishway and to the lake above. Species represented include muskellunge, wall-eyed pike, pickerel, perch, bluegills, sunfish, dogfish, rock bass, crappies, bullheads and suckers. Observations were made in each of three years over a period approximately five weeks in length, including all of May and part of April and June.

## Stream Improvement

We are all familiar with the intense need for trout stream improvement to restore conditions somewhat similar to those existing in the primeval state before man's efforts at logging and agriculture had so altered our streams. Further, we are all familiar with the excellent work which has been done in the state of Michigan by Dr. Hubbs and his associates. I do not intend to go into detail about the needs and methods of trout stream improvement but merely to indicate its great possibilities.

My own state of Wisconsin has recently embarked on what is possibly the most comprehensive stream improvement program ever undertaken in North America. By the use of CCC camp labor and under skilled direction the depart-

ment is improving streams throughout the state. It is the policy of the department to make a demonstration project in each locality so that the sportsmen's organizations, which in Wisconsin are intensely interested in the program, can learn the details and administer the work themselves co-operatively with the state. We look for great things from this program. Its benefits are already being noted. In selecting the crews to be trained in the CCC camps we are choosing local boys so that when they finish their time in the camps they may find an opportunity for employment in carrying on the work they are initiating.

### Lake Bottom Improvement

It is rather interesting that while so much has been talked and written about trout stream improvement little has ever been said or done about improving the natural habitat, the lake bottoms, for the many species of game fish which inhabit lakes. I think that this is a problem even greater in its scope than trout stream improvement, because of the many more species of fish and the many more fishermen which frequent our lakes.

Perhaps it is because lake bottoms are less visible than stream bottoms that we have not assumed they needed attention; but they do. It is my firm conviction that efforts to improve natural conditions in lake bottoms will be just as amply repaid by better fishing as similar efforts in trout streams.

The most pressing need in lake bottom improvement work is to provide hiding places and food production places for small fish. I think it would surprise many of us if we could actually see what happens to the millions of fry and small fingerlings which we plant in our lakes every year. If we are honest we must admit that fishing has not improved proportionately to the increased numbers of fish planted.

There has been some lake bottom improvement work done. Bundles or mattresses of brush have been wired together and anchored to the bottom. Of course these are a help but I believe we need a slightly different type of work and much more of it than we have had to date.

I would like to suggest a possibility of making miniature forests of brush to anchor to our lake bottoms. Long planks or logs could have holes put in them at convenient intervals and brush placed upright in the holes so that when the plank or log is sunk to the bottom the brush would stand upright, creating in reality a miniature forest. This would give ample opportunity for young fish to find hiding places in between the branches and likewise it would provide an opportunity for various types of fish food which develop on twigs, branches and logs.

### Muskellunge Propagation

A report on fish culture could not be considered complete without some reference to actual cultural activities. I would like to discuss briefly what we in Wisconsin have been doing with the muskellunge.

The muskie, without doubt, is the finest and largest game fish native to North American waters. Fortunate indeed are the states and provinces which have muskies in their waters to provide sport for their own fishermen and to attract tourists. The advertising values alone of muskellunge fishing are incalculable in their effects.

Principally because of the extreme and growing popularity of muskies they have been diminishing. I think those of us who live in muskie states and provinces realize that the perpetuation of this species in ample numbers to insure good fishing is perhaps the greatest fisheries problem which confronts us. Those of you who have experimented with this species will agree with me, I am sure, when I say that muskellunge propagation, including spawning, hatching, rearing, and planting, offers problems much greater than with any other species of fish with which we are concerned.

For twenty years or more in Wisconsin we have been propagating muskies and attempting to rear them to a fingerling or larger size.

Our propagation efforts met with varying degrees of success. As far as spawning and hatching are concerned, the degree of success is comparable to and due to the degree of care used in handling the spawn. In good years we have hatched out and planted in the fry stage as many as four million muskies, but I am not satisfied with planting muskies as fry. Consequently, in the last few years we have been concentrating our efforts in attempts to rear them. The biggest obstacle in the way of a rearing program is to provide food for the little fish in ample quantity to insure their healthy growth. This year, with the help of a trained biologist who has had many years of experience in studying the aquatic life of northern Wisconsin lakes, our program has been attended with more than its usual success. Suffice it to say that we are making progress and that within a very few years I hope to have a report which will surprise and please this Society.

In conclusion I would like to make an appeal that we more generally let common sense accompany our scientific efforts and that while not neglecting scientific research and culture we pay more attention to the bodies of water, the lakes, rivers and streams into which the product of our hatcheries is planted. Let us remember that the purpose of our work is not merely to produce more fish in hatcheries but to create better fishing for the North American public.

## REPORT OF THE DIVISION OF COMMERCIAL FISHING

W. A. Clemens

One of the most significant events in the field of commercial fishing has been the development in the United States of a code for the fishing industry under the National Recovery Administration. At my request, Dr. R. H. Fiedler, Deputy Administrator, prepared a statement which is here incorporated in my report.

### Codifying the Fishery Industry Under the National Recovery Administration

Statement by R. H. Fiedler, *Deputy Administrator, National Recovery Administration*

The fishery industry has always been highly individualistic. This has been especially true with the producing or catching branch of the industry. This branch embraces about 123,000 individuals who operate along our entire seaboard, in the Great Lakes area, and in our streams. They have had little contact with

one another, and therefore each has pursued his vocation giving little attention to outside influences, which might have a direct bearing on his own activities. As a rule they are unorganized. On the other hand, there has existed considerable organization among the processors and wholesalers of fishery products in some areas, although in other areas they also were unorganized.

Because of the economic conditions existing in the country after the slump in 1929, the fishery industry became sorely depressed. It began to market its products in a most disorganized fashion; as a result there existed an unstable price level, and customary marketing channels were ineffective in moving production. Fishermen were receiving low returns, wholesalers were unable to carry on, and consumers were paying relatively high prices for fishery products. In addition there existed a situation where an industry worth one billion dollars to the industrial structure of the nation had developed no national plan for the conservation and sustained production of its raw supplies, which constitute one of our great natural resources.

As a corollary to this disorganized situation, and because credit dried up during the emergency, we witnessed the industry indulging in destructive price-cutting, and other detrimental practices which were reflected largely on the fishermen, resulting in lowering their incomes to the point where their very livelihood was in jeopardy. Thus the very evils which the National Industrial Recovery Act was enacted to correct were particularly apparent in the fishery industry; namely, the volume of the products of the industry in interstate and foreign commerce had diminished; the capacity of production units had decreased; the necessity for organization among trade groups was everywhere apparent; and because of destructive price-cutting, the purchasing power of fisherman and processors was reduced, thousands of earners were thrown out of regular employment, and one of our great natural resources was exploited unwisely.

Because of the individualistic nature and unorganized state of the industry it was necessary at the very outset of the work of the Administration to effectuate organization of the industry into trade or industrial associations and groups for the proper presentation of the code to the President for approval. To accomplish this the industry in the first instance organized on a national scale. This was done at a general meeting in Washington, D. C., October 19 to 22, 1933, in what is believed to have been the most representative gathering of this industry in history. At the meeting a national or "basic" code was formulated, and later submitted to the Administration. This code reflected the combined views of about sixty-nine local fishery associations or groups, comprising roughly about 85% to 90% of the industry.

The code was submitted to the Agricultural Adjustment Administration which was then handling the fishery codes, and was later completed by the National Recovery Administration and recommended to the President for approval. The code received his signature on February 26, 1934, and became effective March 22, 1934.

The approved code establishes a National Code Authority for the industry, to administer the code. In addition, in order to promote the policy of the Act and to effectuate the necessary local administration of the provisions of the National Code and care for unique or unusual circumstances, any trade group or associa-

tion in the industry may prepare and, with the approval of the President, adopt a divisional code under the National Code. Each divisional code is to be administered by an Executive Committee with special powers and duties as outlined in the National Code, and which may be further extended, not inconsistent with the National Code.

The National Code covers the entire fishery industry, including the catching or taking from the water, the cultivating, the farming or other artificial propagation (except propagation of goldfish and tropical fish), the processing, and the wholesaling of fish and all other commercial products of aquatic life in both salt and fresh water in the United States, its territories, and possessions, if, but only if, the handler or distributor has also done the processing. It covers also commission merchants trading in products of the fishery industry. It thus is seen that the code embraces the functions of fishing, processing, and distribution. This includes those engaged in the fishing function wherever conducted on United States vessels, that is, within or without territorial waters; the processing function whether on land or aboard United States vessels at sea; and the function of marketing as carried on by a processor. And in addition those firms marketing on a commission basis and known as commission merchants are also included.

In developing the National Code the industry, because of the complexity of the problem, could not care for all the unusual or unique situations existing in all the various branches which required attention. Therefore the National Code contains provisions which have general application throughout the entire industry, and it is intended that the divisional codes will take care of the specific needs of the various divisions of the industry.

In developing the code it was realized early that fishing or the catching of fish is an occupation depending upon the presence of fish, seasons, tides, wind, weather, state laws, and the like. Therefore no limitation was placed on the hours of labor for those engaged in this enterprise. It was known also that individual fishermen receive their income from the sale of the fish they catch and market, and that individuals in the crew of a fishing vessel usually receive their income by sharing in the proceeds of the venture (sale of the fish) in accordance with a prearranged share or "lay" agreement. This is a custom peculiar to the fishery industry, and its origin is lost in antiquity. Therefore no minimum wage was set for those engaged in the fishing function when working on a share or "lay" basis. However, in order to learn whether this system is subject to abuses which may react in unjust returns to the parties to the agreement, the code provides for a study of the various types of "lays" and for reporting on the study to the Administrator for Industrial Recovery.

Other provisions of the code which it is expected will result favorably to the fishermen in raising their income are those relative to open bookkeeping with respect to accounts of profit-sharing agreements, purchases from fishermen, false measures, and dishonest account of sales, as well as a provision which it is expected will minimize or overcome destructive price-cutting, which generally in the long run results in depressed prices to fishermen.

Clerical, accounting, and other office employees are not permitted to work more than forty hours in any week under the terms of the code. Other employees are limited to ninety hours in any two consecutive weeks, with provisions for over-

time pay for workers engaged in emergency maintenance or to prevent spoilage. In these latter cases employees are to be paid time and one-third the normal rate of pay for hours worked in excess of the maximum established for them in the code.

The minimum rate of pay set in the code for clerical, accounting, and other office employees is $16.00 per week, with $14.00 per week for office boys. The minimum rate set for other employees is $13.00 per week in the South and $15.00 per week in the North in cities of less than 100,000 population; and $14.00 in the South and $16.00 in the North in other places.

Realizing that these rates may not be equitable in all branches of the industry, provision has been made in the code to revise the hour and wage rates in the divisional codes.

The unfair trade practices outlined in the code refer to false advertising, misbranding, destructive price-cutting, secret rebates, combination sales, commercial bribery, racketeering, false measures, free deals, reversal of communication charges, dishonest account of sales, return and allowances for containers, purchases from producers, false statement of accounts, and unearned service payments. It is the belief of the industry that the removal of these unfair trade practices will save the industry many thousands of dollars annually, and will also create more stable economic conditions in the business.

Many problems needing attention could not be cared for at the time the National Code was formulated. Therefore the code provides for studies to be made of certain problems, with a view of establishing future policy, and possibly providing a basis for amending the code. One such study already has been referred to in regard to the "lay" or share method of dividing the receipts of the fishing venture. Another will be made of the feasibility and wisdom of establishing a proper system and agency for the grading of products of the industry. This is for the purpose of benefitting the fishermen; for stabilizing the industry; for preventing destructive price-cutting; and for eliminating from the market immature, undersized, inferior, or unwholesome fishery products. The industry believed this study should be undertaken to encourage the distribution of strictly high-grade products and otherwise to protect the consumer against inferior merchandise.

The industry also realized that there exists no national plan for the conservation and sustained production of our great natural fishery resources. In order to formulate such a plan for future guidance, the National Code Authority has pledged itself to meet with various Government conservation agencies. I understand this meeting is being held in connection with this joint meeting of the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners, here in Montreal at this time. In my mind this is a most fortunate and opportune time for the Code Authority to hold its meeting, for it gives those fundamentally interested—the Federal and State governmental agencies, and the industry—a chance to discuss the situation and means for developing a plan. In fact, I believe this is the first time in history these two interests have met together for such a purpose, and I feel that as a result of this meeting a constructive program will be formulated.

Concurrently with the work of preparing the National Code, the Administra-

tion was working on the development of divisional codes as supplementary to the National or "basic" code. In these codes the problems of the various divisions are given detailed attention. Some of these problems have to be met by revising the National Code, especially in the articles relating to hours and wages. In most cases the revisions shortened working hours and increased wages. Other problems necessitated additions or further extension of the National Code, especially in the article relating to unfair trade practices. In addition, provision has to be made for the self-government of the branch of the industry, as each branch under the terms of the National Code has complete autonomy.

The divisional codes may be formulated on a functional, commodity, or regional basis, but usually they are a combination of two or more of these bases. Originally the Administration had application for about eighty-three fishery codes. However, these have been carefully studied with a view toward consolidation, and it is now expected that this number will be reduced to about thirty supplementary or divisional codes under the National Code.

Throughout the entire code program the National Recovery Administration has been working toward effectuating industrial self-government in the fishery industry under governmental sanctions and supervision, with the view of rehabilitating the industry and placing it on a plane compatible with its worth to the nation.
August 28, 1934.
Washington, D. C.

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No attempt has been made on the part of governmental agencies to formulate a code for the fishery industry of Canada. However, encouragement has been given to various sections of the industry in their attempts to meet the many difficulties which have developed during recent years. One phase in particular may be mentioned, namely, the effort to improve the quality of the product. Standards and grades for various kinds of fish, as well as for the containers, have been defined, and by the Fish Inspection Act there have been prohibited the sale and shipment of such fish and packages as come under its provisions, unless inspected and officially marked or stencilled by a properly qualified inspecting officer. On the Atlantic coast, pickled mackerel, pickled herring, pickled alewives, smoked round herring and oysters in the shell are included in the provisions. On the Pacific coast a new system of inspection of dry salted herring was inaugurated and regulations were adopted for the inspection and grading of canned salmon. In the latter case, an inspection board was set up and the main features of the inspection were:

(1) That no canned salmon could be shipped out of the Province of British Columbia without inspection.

(2) That parcels of canned salmon that were found to be fresh, firm, and well packed were granted an official certificate of approval.

(3) That parcels of canned salmon that were found to be sound and fit for human food but not up to the standard to entitle them to a certificate, were to be classed as "second quality" and these words embossed on the additional top attached to the end of the tin.

(4) Parcels which have fallen below second quality grade were confiscated and destroyed or used by the Department for purposes other than human food.

In conjunction with the institution of the systems of grading and inspection, instruction in the curing of fish has been given to fishermen and courses of instruction to departmental officers who have been given the duties of inspection. It is felt that the production of a high grade product is fundamental to the success of the fishing industry.

The following summary of recent legislative enactments affecting commercial fisheries is submitted for the record.

Legislation affecting the fishery industry enacted during the 73rd Congress, 2nd Session.

During the second session of the seventy-third Congress of the United States several pieces of legislation were enacted which affect the fishery industry. The more important of these Acts are as follows:

Authorizing Associations of Producers of Aquatic Products.
(Public—No. 464, approved June 25, 1934)

Under this Act cooperative associations of producers of aquatic products are authorized, and thus these producers have been accorded the same rights and privileges which have been accorded to producers of aquicultural products under the Capper-Volstead Act of February 18, 1922 (42 stat. 388). In brief, the Act permits producers of aquatic products to form cooperative associations for the purpose of collectively producing, processing, and marketing aquatic products.

Loans to the Fishery Industry
(Public Resolution—No. 19, approved April 16, 1934)

This resolution extends to the whaling and fishing industries the same benefits under Section 11 of the Merchant Marine Act of 1920 as amended. In brief, it provides that loans may be obtained for the construction, outfitting, equipment, reconditioning, remodeling, and improvement of vessels engaged in the whaling and fishing industries under certain rules and regulations, and in accordance with certain requirements. The Act is administered by the United States Shipping Board Bureau.

(Public—No. 417, approved June 19, 1934)

This much-needed piece of legislation for the commercial fishing industry provides for loans for the purpose of financing the production, storage, handling, packing, processing, carrying, and/or orderly marketing of products of the American Fisheries. The Reconstruction Finance Corporation administers the Act.

(Public—No. 381, approved June 18, 1934)

This Act, which is administered by the Farm Credit Administration, authorizes production credit associations to make loans to oyster planters for the purpose of cultivating oysters.

Inspection of Seafood.
(Public—No. 451, approved June 22, 1934)

This Act amends an Act approved June 30, 1906, as amended and authorizes a voluntary inspection service for seafood production, under certain rules and regulations. The Act is administered by the Secretary of Agriculture.

Commercial Fishing for King Salmon in Yukon and Kuskokwin Rivers.
(Public—No. 166, approved April 16, 1934)

This amends Sections 3 and 4 of an Act of Congress entitled "An Act for the protection and regulation of the fisheries of Alaska," approved June 26, 1906, as amended by the Act of Congress approved June 6, 1924. The newer amendment permits commercial fishing for King Salmon in the Yukon and Kuskokwin Rivers by native Indians and bona fide white inhabitants of Alaska under such restrictions as may be prescribed by the Secretary of Commerce. Prior to this it was unlawful to prosecute commercial fishing in the above rivers, and also within 500 yards of their outlets.

Regulations Governing Killing Sea Lions in Alaskan Waters.
(Public—No. 372, approved June 16, 1934)

This Act repeals all Acts and parts of Acts prohibiting the killing of sea lions in the waters of the Territory of Alaska, but provides that, in accordance with rules and regulations promulgated by the Secretary of Commerce, sea lions may be killed in the waters of Alaska.

Fishery Research Vessel.
(Public—No. 447, approved June 21, 1934)

This Act authorizes an appropriation of $500,000 for the preparation of plans and specifications, and for the construction and equipment of a research vessel to study our commercial fisheries. The vessel would be maintained and operated under the supervision of the Secretary of Commerce. The Act did not carry an appropriation, therefore actual construction of the vessel can not be undertaken under this Act.

## REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

GUY AMSLER

During 1934 the legislatures of nine states met in regular session. They were: Kentucky, Louisiana, Massachusetts, Mississippi, New Jersey, New York, Rhode Island, South Carolina and Virginia.

There were special or extraordinary sessions of assemblies in a number of the states but such progress as was made resulted from measures enacted during the regular sessions. A brief summary of legislative and regulatory changes follows:

*Kentucky* reduced the bag limit on black bass and trout to ten each, and crappie from 25 to 15, and raised the size limit on trout and bass to 11 inches, at the same time providing a 7-day tourist license at a cost of $1.00.

*Massachusetts* makes the 34th state (including the District of Columbia), outlawing the sale of fresh-water black bass regardless of where taken, and has adopted the part-time angler's license, covering a period of 3 days at a cost of $1.50.

*Mississippi* increased the size limit on black bass to 10 inches, and placed a 4-inch limit on sunfish. This state also added a 10-day short term license to its statutes, at a cost of $1.50.

*New York* reduced the daily limit on lake trout from 10 to 6, shortened the open season on that species one month and on whitefish two months, and prohibited the use of goldfish and carp as bait and limited the size of minnow nets to 36 square feet. In Spring Lake, Cayuga County, the bag limit on black bass has been reduced from 15 to 6 a day, and one of their favorite breeding grounds has been closed to all fishing from January 1st to July 1st.

*North Carolina,* I regret to say, stepped back a pace, by regulation though, rather than legislative enactment, permitting fishing on certain days during the closed season.

*Pennsylvania.* The Board of Fish Commissioners promulgated a regulation prohibiting plug baits with more than one burr hook of three points, applicable to all fishing, including rod and line; and I believe you are all familiar with the Spring Creek project, at Bellefonte, where fly casting only is allowed, and while many fish may be caught, but two may be retained daily. The rest must be returned to the water uninjured. The man or woman fishing that stream may only cast his flies on its waters five times a year, thereby limiting the catch that he may retain during that year to 10 trout.

*Rhode Island* enacted a law permitting licensed Connecticut anglers to fish in Beach pond, located in Exeter, and Kilingly pond, at Gloucester, without a Rhode Island license on condition that Connecticut grant the same privilege to those from Rhode Island.

*South Carolina,* after having provided a 60-day or less optional closed season on Lake Murray, shortened the season thereon 10 days.

*Virginia* adopted a one-day fishing license for non-residents costing $2.00 and adopted a regulation making it unlawful to take any fish from inland waters when same are covered with ice.

*Washington State* under its new set-up provided a statewide closed season on trout, black bass and crappie, and a limit of 20 game fish and not more than 10 pounds and one fish in a day.

During the spring a movement was under way to strengthen the laws in Louisiana by providing a closed season on black bass, as well as other game fish, but unfortunately I am not informed as to the outcome of the movement.

Two measures passed by the recent session of Congress to benefit the supply of game fishes are:

Fish and Game Sanctuaries.
(Public—No. 120, approved March 10, 1934)

This Act, the provisions of which shall be executed by the Secretaries of Agriculture and Commerce, provides for the establishment of fish and game sanctuaries subject to certain restrictions and limitations. It further empowers the above Secretaries to make all rules and regulations for the administration of such sanctuaries as may be established under the Act.

Conservation of Wildlife.
(Public—No. 121, approved March 10, 1934)

The purpose of this Act is to conserve such wildlife as fish and game. It has been known as the "Federal Coordination Act."

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## REPORT OF THE DIVISION OF ANGLING

W. J. TUCKER

Inquiries which I have made have indicated that there have been no revolutionary changes in angling practices during the last year. In the western portion of the country there has been increasing difficulty in the anglers finding a place to fish, owing to the receding of fishing waters. In the coastal region of the United States there has been an increasing interest in tidal water fishing, produced in some instances through leadership given by the state game and fish departments, and following the example set by Commissioner Quinn in Alabama. That has taken a certain amount of pressure off the fresh water areas in those states.

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## APPOINTMENT OF COMMITTEES

*Auditing*—H. H. MacKay, Raymond J. Kenney, Kenneth Kunkel.

*Time and Place*—J. A. Rodd, C. C. Regan, Emmeline Moore, A. B. Cook, Jr., I. T. Bode.

*Nominations*—John Van Oosten, G. C. Embody, Charles O. Hayford, B. O. Webster, A. G. Huntsman.

*Resolutions*—Talbott Denmead, George Stobie, A. F. Byers, T. H. Langlois, J. A. Bellisle.

# REPORT OF COMMITTEES

## AUDITING COMMITTEE

Dr. MacKay: As directed, your Auditing Committee has checked the books and accompanying vouchers of the treasurer for the fiscal year ending June 30, 1934, and finds the report as submitted to be correct.

Mr. Talbott Denmead, United States Bureau of Fisheries, Washington, D. C., accompanied your treasurer to the vault of the Riggs National Bank, September 4, 1934, and assisted him in checking the permanent fund securities of the Society, and the report of the treasurer concerning the said securities was found to be correct.

Your committee recommends that the total appropriation for clerical and stenographic services for the year 1934-1935, exclusive of expenses in connection with the preparation, proof reading and indexing of the Transactions, be the same amount as last year, namely, $350.00.

Your committee desires to commend the treasurer upon the satisfactory condition of the books.

Mr. Thaddeus Surber: I move that the report be adopted.

(The motion was seconded by Mr. Rodd and carried unanimously.)

## COMMITTEE ON RESOLUTIONS

Mr. Denmead: Your committee, composed of Mr. Langlois, Mr. Byers, Mr. Bellisle, Mr. Stobie and myself, have favorably reported on four resolutions which with your permission I will read:

### *Appreciation of Courtesies*

Whereas, This historic sixty-fourth annual convention of the American Fisheries Society is about to adjourn; now

Be It Resolved, That the American Fisheries Society at its sixty-fourth annual convention assembled in Montreal, Canada, September 14th, 1934, hereby expresses to the province of Quebec, the officials of this great city of Montreal, the Canadian Government, the management of the Windsor Hotel, and also to the individuals and organizations that have made the conference so successful, enjoyable and profitable, its sincere appreciation of the fine hospitality and gracious courtesies extended its members and guests during the meeting.

### *Conservation Radio Broadcast*

Whereas, Through the kindness and courtesy of the National Broadcasting Company, and Mr. Frank E. Mullen, Director of Agriculture, Chicago, the interests of conservation have been forwarded through the regular Farm and Home Hour, therefore,

Be It Resolved, That the American Fisheries Society at its sixty-fourth annual convention held in the city of Montreal, Canada, September 12th to 14th, 1934, hereby expresses its thanks and appreciation to the National Broadcasting Company and Mr. Frank E. Mullen, Director of Agriculture of the company, for

their cooperation in presenting each week during 1934 a Conservation Program, which has materially forwarded the aims of those who are working for better conservation of our replaceable natural resources.

### *Pollution*

WHEREAS, Pollution constitutes one of the most serious menaces to aquatic life, as well as to recreation and public health; and

WHEREAS, There seems to be a wide variance in the laws controlling pollution, and the administrative machinery for the execution thereof:

THEREFORE, BE IT RESOLVED, That the president of the American Fisheries Society be requested to appoint a committee of not to exceed fifteen to study the entire problem of coastal and inland water pollution, including a summary of past studies, and to submit at the next meeting of the Society a report of its findings, with their recommendation for remedial steps. The committee so appointed should be authorized to cooperate with other organizations, individuals and similar committees interested in the pollution problem. (See page 5 for names of members on this committee.)

### *Committee on Amendment of Constitution*

WHEREAS, It appears that in certain respects the constitution, by-laws, and procedure of the American Fisheries Society are not entirely adequate to meet the needs of a growing active organization, it is recommended that a committee of three members be appointed by the president to consider these matters and make recommendations for their modification and improvement at the next meeting of the Society.

(The resolutions were unanimously adopted.)

THE PRESIDENT: Is it the recommendation of the Resolutions Committee that the Committee on Amendments to the Constitution be appointed before we adjourn?

MR. DENMEAD: There is no specific direction in that regard, but it is a matter that might be considered.

THE PRESIDENT: I will confer with the incoming president, and the personnel of the committee will be announced later.

(The President later announced the appointment of Eben W. Cobb, Chairman, Charles O. Hayford and T. H. Langlois as a Special Committee on the Revision of the Constitution and By-Laws, with instructions to report at the next meeting.)

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## COMMITTEE ON TIME AND PLACE

MR. J. A. RODD (Ottawa, Ontario): The joint committee of the two organizations held a meeting at noon and considered a very large number of invitations to meet at various places.

The formal report of the committee is as follows: The Committee on Time and Place of the International Association of Game, Fish and Conservation Commissioners, and the Committee on Time and Place of the American Fisheries Society, have met jointly and selected Tulsa, Oklahoma, as the meeting place

for the 1935 convention. Your committee recommend that the dates be fixed by the officers of the two associations and the local committee.

I move the adoption of this recommendation.

MR. REGAN (Kentucky): I second the motion.

MR. TUCKER (Texas): I realize that it is not customary in this Association to appeal from the recommendations of an appointed committee. The chairman of your committee announced to me that any sort of objection would be an innovation, but it seems to me that in a Society as old and honorable as this it might be well to have an innovation.

I come from Texas. I presented the claims of that state before your committee. For many years—nine years, to be exact—I have been attending your meetings, and in doing so have personally travelled 16,000 miles. Texas believed it had served its apprenticeship in this association, and that it was entitled to consideration; therefore I was much surprised when I found that the committee presided over by my good friend Bob Chandler of Oklahoma had selected his own state for that purpose.

Let me tell you that we are glad to know that you did give some consideration to the Southwest, and it is deserving of consideration. All of you have looked at the map of the United States, and you must have seen that Texas bears on one shoulder Oklahoma and on the other New Mexico. I would not make this appeal to the members of this organization if I had not first canvassed the membership, and did I not know, as I do now, that they will support me in the contention which I am making. Ours is an historic country, the only state in the Union that has been under six flags. We have our historic battlegrounds, a land dotted with missions, a seashore incomparable. Our game and fish resources are worth consideration, and I believe you would find much to entertain and interest you in that great state, which is one-twelfth of the area of the United States, so that in all fairness you should meet every twelfth time in Texas, yet you have never met there.

Now, I offer you a substitute for the motion of the committee, Mr. Chairman. I desire to substitute for Mr. Rodd's motion a motion that we accept the invitation of the state of Oklahoma by a rising vote.

(The motion was seconded by Mr. Cook and carried unanimously by a rising vote. The dates of the 65th Annual Meeting were later fixed for September 9, 10 and 11, 1935.)

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## COMMITTEE ON NOMINATIONS

DR. VAN OOSTEN: In considering the slate of officers the committee, following the past custom, has attempted to have every section of the United States and Canada represented. In the case of certain recommendations we have emphasized the representation of the southern states in view of the fact that the next meeting is to be held in Oklahoma. We have also attempted to have representation from the various activities of the Society, and have made every effort to select active members.

Your committee submits the following report:

*Officers*

*President*—E. L. Wickliff, Columbus, Ohio.
*Vice-President*—Frank T. Bell, Washington, D. C.
*Secretary-Treasurer*—Seth Gordon, Washington, D. C.
*Librarian*—Eben W. Cobb, Hartford, Conn.

*Vice-Presidents of Divisions*

*Fish Culture*—A. B. Cook, Jr., Ionia, Michigan.
*Aquatic Biology and Physics*—A. H. Wiebe, Austin, Texas.
*Commercial Fishing*—James N. Gowanloch, New Orleans, La.
*Protection and Legislation*—Guy Amsler, Little Rock, Arkansas.
*Angling*—Talbott Denmead, Baltimore, Md.

*Executive Committee*

A. G. Huntsman, *Chairman*—Toronto, Canada.
I. T. Quinn—Montgomery, Alabama.
Thaddeus Surber—St. Paul, Minnesota.
S. B. Locke—Chicago, Illinois.
Sumner M. Cowden—Albany, New York.
B. O. Webster—Madison, Wisconsin.
Wm. Ray Allen—Lexington, Kentucky.

*Committee on Foreign Relations*

James A. Rodd, *Chairman*—Ottawa, Canada.
James Brown—Montpelier, Vermont.
John L. Farley—San Francisco, California.
Frederic C. Walcott—Norfolk, Connecticut.
W. F. Thompson—Seattle, Washington.

*Committee on Relations with Federal, Provincial and State Governments*

Charles E. Jackson, *Chairman*—Washington, D. C.
H. H. MacKay—Toronto, Canada.
O. M. Deibler—Harrisburg, Pennsylvania.
W. J. Tucker—Austin, Texas.
Harry B. Hawes—Washington, D. C.
Wm. C. Adams—Albany, N. Y.
T. H. Langlois—Columbus, Ohio.

In addition to this formal report the Committee on Nominations would like to make an informal report to the Chairman of the Council. The committee recommends to the Chairman of the Council that, in order to secure better representation, the following be added to the personnel of the Committee on Scientific Names of Fishes: Mr. Walter H. Chute, Director, Shedd Aquarium, Chicago, and Dr. A. H. Leim, St. Andrews, New Brunswick. The committee feels that representation of the aquaria of the country is desirable because no group of people are more familiar with the common names of fishes than those employed by

the aquaria. Dr. Leim is nominated for the committee because he is very familiar with the common names of the marine fishes.

THE PRESIDENT: You have heard the report of the Committee on Nominations; what is your pleasure?

MR. LANGLOIS: I suggest that the report be accepted as presented.

(The motion was seconded and carried unanimously.)

THE PRESIDENT: Before inducting the new president there are one or two announcements I believe I should make. In line with the informal report presented by the chairman of the Nominations Committee I want to add to the Committee on Scientific Names of Fishes Dr. A. H. Leim and Walter H. Chute. In collaboration with the incoming president I have been asked to announce a Publications Committee to work with the secretary in the compilation of the Transactions of the sixty-fourth annual meeting. The committee will consist of Dr. A. H. Leim, Dr. John R. Greeley and Dr. A. H. Wiebe.

I have also been asked to announce a committee on Pollution. The personnel of the committee is not yet complete, and is also subject to the acceptance of the members I will name, as follows: Hon. Harry B. Hawes, Chairman; Talbott Denmead, Secretary; S. B. Locke, Seth Gordon, Milton P. Adams, Dr. M. M. Ellis, Dr. John Van Oosten, C. M. Baker, Carl D. Shoemaker.

The other members of this committee will be announced later by your new president.

At this time I would ask Mr. S. B. Locke and Mr. T. H. Langlois to escort the new president to the chair.

(Applause.)

Mr. Wickliff was escorted to the chair.

THE RETIRING PRESIDENT: Mr. Wickliff, in greeting you as president of the American Fisheries Society I want to extend to you my best wishes, to congratulate you upon the high office to which the members of this Society have elected you, and to assure you of my support. Before leaving the chair I wish also to thank all the officers who have cooperated so splendidly with me in this program.

THE PRESIDENT ELECT: Thank you, Mr. Westerman; I congratulate you upon the way you have handled the affairs of the Society during the past year.

Members of the American Fisheries Society, I desire to express my thanks for the honor you have conferred upon me. You may rest assured that during the next year I shall make every effort to promote the interests of the Society, as Mr. Westerman has done during his year of office.

The hour is late; I realize we all desire to leave as soon as possible and if there is no other business a motion to adjourn is in order.

MR. DENMEAD: Before we adjourn I think this meeting should express its thanks to our outgoing president for the hard work he has done in the interests of the Society and congratulate him upon his success in handling the affairs of the organization during the past twelve months. I will put that in the form of a motion.

DR. VAN OOSTEN: I will second the motion.

The President Elect: It has been moved and seconded that the thanks of the Society be extended to our past president for his untiring efforts in the promotion of fish culture, scientific research, and the other interests of the Society. Let us show our appreciation of his efforts by rising and greeting him as best we can.

The members rose, with prolonged applause.

The Retiring President: I assure you, members of the American Fisheries Society, that it has been a distinct pleasure for me to be permitted to serve you in my own humble way as best I could. Again I thank you for your many kindnesses and for the cooperation I have received at the hands of all the other officers and the members generally.

The President Elect: If there be no further business a motion to adjourn will be accepted.

On motion of Mr. Langlois, seconded by Dr. Van Oosten, the sixty-fourth annual meeting of the American Fisheries Society was adjourned.

The Secretary: Before adjournment I would like to call attention to the number of representatives present from the several states and provinces. Quebec had twenty-nine registered; New York, twenty-five; District of Columbia, sixteen; Ontario, twelve; Texas, twelve; Ohio, eleven; Michigan, ten; Massachusetts, seven; Illinois, six; Kentucky, five; Vermont, four; Pennsylvania, four; Alabama, Arkansas, Nebraska, Maine, each three; Iowa, Connecticut, New Hampshire, Florida, New Jersey, Virginia, Kansas, Minnesota, West Virginia, Wisconsin, Indiana, two each; Washington, Oklahoma, Tennessee, Missouri, Maryland, one each. There were numerous others present who failed to register, but this summary indicates the widespread representation and interest we have had at this 64th Annual Meeting.

# In Memoriam

Davis Baker, New York

Guy Cary, New York

E. S. Casselman, Ohio

C. G. Corliss, Massachusetts

Irving H. Dunlap, District of Columbia

E. H. Eaton, New York

W. deF. Haynes, New York

George R. Hogarth, Michigan

Edmond Perrier, France

W. deC. Ravenel, District of Columbia

Henry A. Schuil, Michigan

Edward W. Sheldon, New York

William D. Stewart, Minnesota

Harry C. Trexler, Pennsylvania

Robertson S. Ward, New York

Judd S. Weaver, Nebraska

E. Hamilton White, Canada

P. G. Zalsman, Michigan

(This list includes those who died since the last Annual Meeting)

# PART II
# PAPERS AND DISCUSSIONS

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# THE NEED FOR A MEASURE OF THE ANGLER'S CATCH

G. H. CLARK
*California Division of Fish and Game*

How many of us would spend our money hit-or-miss, disregarding the size of the purchase or its usefulness, and without knowing how our bank balance stood? How many manufacturers would produce at capacity without some knowledge of what is likely to be consumed and of their working capital? How many conservation agencies know what the annual consumption of angler's fish is in fish taken from the water; what the balance left in stream or lake for breeding stock is; how much the planting of fish has increased the catch per man or per hour of fishing; or whether the increase of fish through artificial and natural means is balancing the catch? How many can answer these questions with certainty? Unfortunately, very few. How many have even tried to find the answers to these questions by devising some method of collecting data? Again, the same answer.

Let us face the facts. Isn't it true that, in order to make wise plans, we must have knowledge; we must know what we have on hand and whether that supply is decreasing or increasing from year to year? Is this not a basic fact, a foundation for all other work? For with this knowledge, can we not better determine what the stocking policy should be for various waters, natural conditions being favorable? Should we not know how much our fish planting is augmenting the natural supply and, so, the catch? Should not the knowledge of supply be one of the basic factors for the regulation of fisheries, the closing of streams, the making of size limits and the determination of fishing seasons?

We are working toward one objective. We wish to take or catch the maximum amount of fish without endangering the future supply. We can supplement the natural population by artificial means in a great many instances, but we must find the balance between catch and supply, both natural and artificial. To discover this we must know over a period of time what is taking place, whether the supply is on the increase or decrease in the various localities.

Now, to determine this increase or decrease of supply, we need not know the exact number of fish in a stream or a lake each year. It is fortunate this is true for, if it were not, our task would become almost impossible. All we need is a measure from year to year that will enable us to ascertain the availability of fish to the fisherman. Such a measure will give a gauge of whether or not the supply or availability is increasing or decreasing.

All this is not new, particularly when dealing with the commercial fisheries throughout the world, for almost all the important fisheries are measured in just this way—by obtaining the catch per unit of fishing effort. Some states, notably Michigan, have made a consid-

erable start in collecting and analyzing the angler's catch to determine the availability of fish to the fisherman through a measure of the catch per fishing effort.

We, in California, have had considerable experience in the collection and analysis of our commercial fish catches, the largest of which are the ocean fisheries. Our problems have been and are the same as all of us face in regard to the angling catch. We must allow the maximum catch without depleting the future supply, always being sure that we have a surplus for the continuance of the population. We must find that point where catch balances supply but leaves a surplus or "backlog" if we are to enjoy our fisheries for any length of time. The commercial catch statistics in California are the foundation of our research work, as they are in many other places, and together with our other studies give us the knowledge by which the fisheries are regulated.

Unlike the angling catch, the commercial catch figures are comparatively easy to collect because all the fish are sold and the collection of records can take place at the first transaction. With the angler's catch some different method of collection must be devised. The most practicable one seems to be for the angler to keep his own record and send it in to the proper agency for compilation and later, when the season is over, analysis of all the returns can be made.

Through the contact of the conservation agency with the angler when he buys his fishing license, there is an opportunity to distribute forms for the use of the fisherman in making out a record of his catches during the coming season, to instruct him as to the system's value and its use or to supply him with literature describing the system, or both.

The forms on which the angler is to keep his record should be convenient to carry, simple in construction, but carry full details for the record, such as species of fish, size, locality and waters fished, hours fished and any other desired information so that a measure of the availability of fish to the fisherman per unit of fishing effort may be obtained. These forms should be handy to mail, addressed and postpaid. Make everything as easy as possible for the recorder so that, once arousing his interest and getting his cooperation, he will not give up because he has too much work to do sending in his record of catch.

Much can be accomplished with the aid of the wardens in the field who are constantly checking creels and licenses. These men are in contact with the fishermen at all times and should talk about the gathering of the catch records to those they meet on the streams. They should be supplied with extra form cards and, if necessary, help the angler fill out his record. Constant following up and pushing is what will put a system of this sort across.

After a system for the collecting of the angler's catch has been

devised, give it ample publicity through every possible means before it is put into operation. Newspapers, conservation magazines, talks before clubs and sportsmen's gatherings all will aid in enlisting cooperation of the anglers. Explain the idea, its workings, its use and its value, to the fishermen who are primarily interested. Get them behind the movement—for without their cooperation, the thing will be a failure. Once the anglers are convinced of the system's usefulness they will be for the plan, but it will be necessary to keep pushing all the time—for nothing will run itself.

There is one other small item we should consider and that is, when instructions are made for filling out forms, use the word *please*. Do not make it an order. You may be surprised at the number of people who will react to that word.

We have put off too long this matter of a measure of the angler's catch. Why not do some thinking about it and then act, so that at least a representative sample of the angler's catch may be used to measure the availability of fish to the fisherman by gauging the catch per unit of fishing effort? With definite knowledge of the supply in the various bodies of water, regulation and administration of our fish resources will be on a much firmer foundation. We will have facts, not just hearsay and poor estimates.

## Discussion

The Secretary: I may say for the information of those who were not at the meetings of the International Association yesterday that among the supplemental recommendations for legislation which the Model Game and Fish Bill Committee presented to the International Association, and which was adopted, was that all states adopt a creel and bag report requirement. It will be noted that that fits in exactly with this particular paper. I simply wanted to mention it so that you will know where to find that recommendation if you want to look it up later.

Mr. Percy E. Nobbs (Montreal): Apparently the burden of the remarks we have just heard read is a matter of filling out forms and making returns. Well, if good judgment is used by those who receive the returns, and they are quite satisfied to consider that the returns represent about ten or fifteen per cent of what actually happens, then the returns might be of some use. Personally I haven't very much faith in returns or in regulations for the bag. The trouble about these regulations is that they usually cover a very wide area and affect a large number of rivers. For instance, we have limit regulations affecting trout and bass in the province of Quebec. We have limit regulations affecting salmon and many other fish in Nova Scotia, and as far as these limits are concerned they fail to achieve respect. In the first place, a great many people, especially the local people, do not pay any attention to them. In thinly populated areas it is very difficult to keep a check on everybody; besides, there is so much local feeling, and so on, that the local man never gets pulled up.

Now, the other aspect of the thing is exactly what happens, and any of you can satisfy yourselves about this by investigating bass fishing in this province as

conducted in this or any other year. There is a limit; I forget for the moment, not speaking with the book, whether it is twenty-five or some other figure, but we will call it twenty-five. What happens? The anglers go forth and they catch seventy-five, a hundred and thirty-five, any number at all; all the fish in excess of the limit they return to the lake, pond or stream, and the rest they bring home. By throwing these fish back into the stream at certain seasons of the year they may do far more harm than would result from their taking the fish away, because damaged fish, fish with the slime off their scales, are open to a great number of infections. In Nova Scotia there is a perfectly glorious limit for salmon; I think it is twenty-five, but nobody in Nova Scotia ever gets twenty-five salmon in a day. That is done simply for advertisement. Salmon fishing is free in Nova Scotia; anybody in that province knows that an angler is doing extremely well if in six days' fishing he gets seven salmon—very well indeed. However, it looks awfully well for the purposes of tourist advertising to use the word "limit," making it twenty-five salmon or something of the kind.

There is an alternative method, Mr. Chairman, which I would like just to mention, and I know it works. It is the method which is in vogue in many of the fishing waters of Finland, where the peasant proprietor happens to be the riparian owner. It is the method in vogue in south central Germany, Australia, Tyrol, and elsewhere, where the fisheries are run by the government or municipal authority, and that is that the angler pays for what he takes in weight. Of course these are very thinly populated countries, but through the properly recognized guides' associations, and so on, it could be worked.

This method is not general all over Europe, but it works splendidly in a great many areas in preserving the fishing. The angler pays for what he catches in pounds weight, and that is so much better than regulations which can be absolutely knocked into smithereens by catching your quota and then going on and damaging a whole lot more fish, and it is better than having the law of the province suggest as a bait for tourists that the fishing is a great deal better than it is by putting on a limit which nobody ever reaches.

Mr. Russell F. Lord (Vermont): I had a little trouble this summer in this matter of collecting statistics. I tried in our Vermont waters to establish just one stream in which the fishermen were requested to report the fish taken from the water during the open season. To make it easy I put up a series of metal boxes, painted a brilliant red, with a large sign asking the fishermen to "please cooperate" and to "please fill in the cards" with which they were supplied. Lead pencils were tied to the boxes with strings; everything possible was done for the convenience of the fishermen in order that we might obtain from them an accurate idea of the number of fish that came out of that one stream.

The first day they did pretty well; I would say, figuring those who did not fill in their cards, that at least a thousand legal trout were taken from that one stream. The season went on, and after the excitement in the newspapers had died out I got tired of interviewing every man and practically filling in his card for him. I found my pencils missing; some of the boxes would have holes shot in them, and some of the comments on the cards under "remarks," where the fishermen were supposed to state their personal feelings about the stream, were

more than interesting; they were obscene and insulting. One man would say the fishing was fine; the next man would say we had better get busy and stock it. Others would ask us to leave out rainbows and put in this and that, and it was not long before I was beginning to be pretty much discouraged.

I think the main thing to do is to make the people that go out with the rod want to help; it is a system of education. Unless a man wants to help improve the fishing, he won't be bothered filling in a card; he won't do anything. It is a pretty difficult thing to change human nature. In fact, there is one entry on my own fishing blank that I have not yet filled in.

THE PRESIDENT: I would like to supplement what Mr. Lord has said; he might well be relating our experience in Michigan. We too have undertaken some creel census work on our inland waters, with about the result that Mr. Lord has mentioned. On one stream in one of the state forests where we undertook to try to get one hundred per cent returns with public cooperation, we failed miserably. The only instances in which we got in a satisfactory number of cards was when the conservation officer interviewed the fishermen on the lake or stream as they were coming off.

Three or four years ago we had 20,000 cards printed that we distributed among sportsmen throughout the state, and I do not believe we got 200 of them back. But through our officers scattered over Michigan we have built up, we feel, some quite valuable data on catches. In our experience, however, it must come only through the officer; we simply are not getting adequate returns from the public.

MR. THADDEUS SURBER (Minnesota): We attempted the same thing last year on one of our southeast Minnesota streams, and when we went to check up on how it was working we found the results unsatisfactory. Our arrangements in the matter were similar to those Mr. Clark has mentioned in his paper. I sent a man in to see what was actually going on. He spent an afternoon on this particular stream, the south branch of the Whitewater river, during the course of which he passed and talked with eleven fishermen. One or two of them, I believe, refused to say whether they had caught any fish or not, but the most of them told him what they had caught and showed him the fish. Just before dark he passed and repassed these stations where they were supposed to record their day's catch—the men had left the stream by that time—and in no instance did he find any record made by any of these men. We were trying to get some data on what was happening in this stream as a result of our plants made over a period of the last three years, but the net result of our efforts to get information on that particular stream was nil. The sum total of fish actually recorded as having been taken out of eleven miles of stream was somewhere around twenty-five or thirty, whereas we know that thousands of trout were actually taken out of the stream.

It seems to me that any effort on our part to obtain such information from anglers is wasted, for two reasons. One is the desire of the fisherman to refrain from letting even his closest friend know where he is catching his fish, and the other is a desire to obtain, by adverse reports on the fishing in the stream, more fish with which to restock it.

# WATER CONSERVATION

Frank T. Bell
*Commissioner, U. S. Bureau of Fisheries*

By the time this meeting comes to a close we will have heard many discussions on fish culture, aquatic biology, stream improvement, and on all matters pertaining to fish from the cradle in a hatching trough to the grave in a sportsman's creel. These investigations and the reports thereon are most vital factors in our plans for multiplying the ranks of satisfied fishermen. I believe we are working on a very shaky foundation, however. For, unless we give some consideration to the most basic factor in a fish's life, namely, water, we overlook the most essential element for fish life. I come from a section where $H_2O$ looms much in our existence, and I feel strongly on the matter of providing plenty of water. The past season has brought the necessity for bringing this fact home to millions of people who for the first time in their lives have looked out on sun baked mudbanks where formerly a lake rippled, and on dusty ditches that were once sparkling brooks.

Water is life, in fisheries work as in other walks, and somebody has got to give some attention to furthering a supply. Roughly and briefly, I view the water problem as being divisible into the following aspects:

1. Hydroelectric, reclamation, or similar developments affecting water resources must be planned and developed, with due consideration to the possible detriment or benefit to fish life.
2. Any land management or improvement programs where any aquatic resources are involved shall include provision for the development of these resources.
3. It must be emphasized, again and again, that the impounding of water for the sake of water and recreation alone is essential for the best interests of the conservation of fish life.
4. There must be a broadening of the present limited efforts to prevent the gradual elimination of public fishing waters by their purchase or lease into private ownership, with subsequent prohibition of public fishing.

I consider these factors vital in the production and conservation of the raw material of good fishing, namely, water, and I ask your indulgence for a few additional moments in order to discuss briefly these factors. Under 1, hydroelectric and irrigation reservoirs may be detrimental to fish life unless they are managed so as to give the fish a chance. Frequent drainage of the reservoirs, unprotected turbine intakes, dams with no provision for passing migratory fish, failure to remove trees, timber and underbrush, with consequent pollution of the water, are all considerations which have a bearing on whether these newly created artificial lakes will have anything to offer to the

fisherman. However, we can not stop progress. Irrigation and hydroelectric development will go along in its own sweet way, but I believe that we should at least have the privilege and right to demand that the fisheries administrators be given the right to point out how such areas can be constructed and managed so as to yield a by-product of good fishing.

With regard to my second theory relative to land management programs, it is going to be difficult for the sponsors of these various projects of reforestation, soil erosion, subsistence homesteads, regional development, etc., to locate land where there will be absolutely no possibilities of conserving or using water. The water will be there to be ignored or else developed as one of the resources which will produce additional recreation, additional food, and other benefits to the fortunate individuals who will live there. For example, by the mere act of creating migratory bird refuges for water fowl, we have a possibility of putting in a good lick for the fish. If the natural resources of the country are to be restored, let's restore them with a thought for the fisherman.

My third point was the necessity of impounding water for water alone. The Dakotas now have this point well in mind and I understand are developing artificial lakes for storage alone without any definite idea that any individual or group of individuals is going to benefit directly by generating electric power or by irrigating fields. The idea is to have the water itself—as the end and not the means. The water, of course, means additional fishing areas and recreational centers. In the southern states this sort of thing has long been practiced under a somewhat different setup. It seems to be one of the chief ambitions of a southern land owner to build a dam and establish a pond on his acres. Hundreds of these artificial lakes and ponds are constructed each year. They are, it is true, private; but they are not without public benefit, since it is generally found that the owner has a wide circle of friends who fish his pond once it is stocked, and to this extent relieve the pressure upon public waters and leave them more free for the sport of the poorer class. I submit that the man who puts up hard cash to increase the water area of this county by some hundreds of acres is a benefactor even though he does not authorize the world-at-large to participate in this fishing. We do not want to be too anxious to tie our water conservation problems in with the programs of the irrigationists and the power development sponsors. We want to stand on a platform of water for the sake of water, fish, birds, and recreation.

Finally, I believe that the administration of fisheries matters in the public interest most insistently demands that the lakes and streams which have been up to the present free and open to public fishing must remain in this category. Their retirement into private ownership by lease or purchase may remove a greater mileage or acreage of accessible public waters than will be replaced by all the artificial lakes, reser-

voirs, etc., which may be constructed. We will be fighting a losing game unless we can show a net increase in public fishing waters.

Pollution is another aspect which might be discussed in connection with this subject, but it is already quite vividly in the minds of most of us. I suppose the fish culturist and the biologist have a right to demand that some one see to it that there will be a sufficient water area to accomodate the fish which are to result from their labors. This rather puts it up to the fishery administrator to steer his course so that in the face of wholesale fish production there will be no lack of places to put the output. Just at the present if the remarks of some of my fishermen friends are to be taken at face value the ratio of fish to water is all in favor of the water. It requires no prophecy to realize that this may not always continue, particularly if we experience a few more drouth years.

I have trespassed on your time to present these random remarks, not with the idea of offering them as a conclusion to a problem but rather as the introduction to a problem which we will all be considering more fully in years to come. I hope that my remarks will furnish something to think over when your own, more immediate problems are laid aside for a moment.

# EFFECT OF 1934 DROUGHT ON FISH LIFE

M. C. JAMES
*U. S. Bureau of Fisheries*

The effects of the 1934 drought in the West and Middle West will be so disastrous from all angles that the harm to fish life may be considered a minor phase. Nevertheless, the welfare of the fish population is of interest to millions of people and if the fish have suffered seriously, the effects will be felt for several years to come.

Accordingly, the Bureau of Fisheries felt that the collection of information on the conditions of fish life in the stricken area would be timely and sought these data from the best informed sources, namely, the State fish and game departments. The statements following, therefore, summarize the comments of the State fisheries authorities and the entire credit is due those agencies which cooperated generously in making it possible for the Bureau of Fisheries to present this information in concise form.

The public conception of the loss of fish from drought, pictures stream beds entirely dried up with tons of fish rotting on sun-baked banks. While this may occur, it is evident that the situation is more complicated and that the more obscure and indirect losses may be the more serious. However, this condition is brought out in the report by individual States. Let me present the views of the men who have the first-hand information.

## MISSOURI

*Conditions*

A considerable loss of fish has occurred. Sixty thousand pounds of large coarse fish were lost in one lake within 3 days. It is believed that the loss is due to depletion of oxygen and concentration of fish. Game fish mortality was lighter than coarse fish.

*Remedial measures*

Six rescue crews in the field salvaging fish from drying waters.

## WISCONSIN

*Conditions*

Damage slight. Streams and lakes are low, but without serious detriment to fish life. Possible damage to natural food supply.

*Remedial measures*

## MICHIGAN

*Conditions*

Streams and lakes low, but little indication of loss of fish life. Most serious condition in southern part of lower peninsula. No definite record of loss of game fish. Hot weather has caused critical water temperatures for certain species.

*Remedial measures*

## South Dakota

*Conditions*

Extremely low water levels have brought about very serious conditions. Fish are dying and it is possible that survivors will be killed during the winter. Fish have been forced into concentrated areas where the decay of aquatic vegetation has added to the stagnant condition. Lakes have been opened to public spearing and seining as the waters have receded to depths of one to two feet.

*Remedial measures*

As many fish as possible are being transferred to artificial lakes where conditions are better. It is suggested that intensive fishing of enemies is only a secondary means of minimizing the loss.

## Indiana

*Conditions*

Lakes and streams in northern Indiana have receded to unprecedented levels. Concentration of fish in streams exposes them to enemies. The forage fish are being affected and being forced to deeper water where they are subjected to other predatory fish. Little indication of actual loss of fish directly from drought. Satisfactory spawning season occurred prior to the worst onset of dry weather. Necessary to remove fish from hatcheries in advance of normal season due to shortage of water supply.

*Remedial measures*

Suggest establishment of broad policy to meet menace of alternate flood and drought.

## Ohio

*Conditions*

Streams exceptionally low and dry and many are reaching critical stage. Additional difficulty appeared in the development of excess vegetation in the lakes.

*Remedial measures*

Fish rescue truck placed in field and local conservation officers notify headquarters when services of truck are needed to salvage fish. Suggested that the Federal Government in cooperation with the State launch a program of lake and stream control to improve habitat.

## Wyoming

*Conditions*

Streams in mountain sections holding their own and no loss of fish expected. In lowlands a number of creeks are completely dry and heavy loss of fish.

*Remedial measures*

Stream control work, particularly dams and retaining ponds, have been a boon to fish life. Artesian wells have been drilled close to creeks thereby maintaining a water supply adequate for fish life.

## Illinois

*Conditions*

Larger streams very low and smaller streams nearly dried up. A great many dead fish observed. Loss attributed to depletion of oxygen aggravated by increased pollution due to reduced flow. Many sloughs in back-waters of streams are dried up entirely. Effect of drought is expected to be felt for several years. Vegetation has been affected by exposure and disintegration has had the effect of pollution.

*Remedial measures*

Rescue crews have been actively at work salvaging fish, particularly from landlocked sloughs.

## Nebraska

*Conditions*

Most disastrous situation in the last 30 years. Many streams and lakes completely dried up involving loss of thousands of fish. It is felt that the actual drying up of the lakes and streams is the most important factor and losses from other conditions secondary.

*Remedial measures*

Fish salvaging crews have been at work, but owing to heavy vegetation and extremely hot weather, rescuing of fish has been difficult.

## Oklahoma

*Conditions*

Lakes and streams drying up and situation serious. It is reported that the shortage of water is the sole cause of loss of fish. It is held that lack of vegetation or pollution are of little significance.

*Remedial measures*

Salvage crews in cooperation with the State or sportsmen have rescued approximately one million fish in a period of 2 months.

## Iowa

*Conditions*

Loss of fish due to receding waters has not been great due to efforts of conservationists and sportsmen and the Department in alleviating the situation. Most seriously affected are small ponds and reservoirs in southern part of the State, where drought has been most intense. Avoidance of greater loss in this area will be dependent upon adequate rainfall.

*Remedial measures*

Intensive fish rescue work has been followed. In comparison with two crews normally used on inland waters, four and five crews have been in the field. Fish and Game Commission supplies rescue nets to Deputy Wardens to take care of emergency calls where the ponds are small and conditions permit use of small nets.

## Colorado

*Conditions*

Actual loss cannot be estimated but has been very serious. Lakes and reservoirs have been drawn to the lowest levels, larger streams have been decreased in flow with tributary streams dried up entirely. With lower waters the concentration of fish has produced limit catches and a large number of fishermen have been in the field. Sale of non-resident fishing licenses in excess of last year. Further loss occurs in irrigation ditches. Aquatic vegetation has been reduced but it is felt that the worst period is over.

*Remedial measures*

Distribution of trout has been only to large streams and lakes where danger of freezing is at the minimum. Department holding over as many trout as possible for distribution when conditions improve. Warm water fish in Plains section of the State have suffered, but rains have improved the situation.

## Utah

*Conditions*

Considerable damage has occurred. Much of the water consists of artificial reservoirs and the demand has caused the drainage of these reservoirs. Silt and debris have made it impossible to salvage many game fish when drainage occurs. Larger dams which still have water will be drained later with additional loss of fish. Utah Lake is so low that it is expected all fish life will freeze out during the winter. Irrigators are destroying beaver dams to secure the last drop of water, and the State's fish program has been set back several years.

*Remedial measures*

It is recommended that provisions be worked out with the Reclamation Bureau, whereby additional water could be stored to eliminate complete drainage of reservoirs every three or four years.

## Arkansas

*Conditions*

Loss of fish will range from 25 to 50 per cent in case of all species. There has been enormous mortality during summer months. Little loss from overfishing, but are concentrated in open waters, becoming prey to predators or suffering from reduced food supply. Supply of fish is affected by drying up of sloughs, bayous, and lakes which are normally little fished for game varieties. These serve as refuges during the summer and restock larger waters. Drought has gotten practically all of the fish inhabiting these areas and the future stock will suffer accordingly.

*Remedial measures*

A great deal of rescue work has been performed, but shortage of funds and facilities have restricted this activity below the actual needs.

### Idaho

*Conditions*

Streams and lakes affected to an alarming extent resulting in collection of fish where they may be taken without effort by fishermen. Natural food is affected detrimentally. An unusual harm lies in the fact that drainage of reservoirs will derange the spawning of trout during the coming season and limit natural reproduction.

*Remedial measures*

It is suggested that hatchery facilities will have to be intensively operated to supply fish for restocking ponds where natural reproduction has been seriously curtailed.

### Kansas

*Conditions*

The drought has completely depleted the fish life in numerous streams. The recovery to normal conditions will be greatly delayed with the supply of fish available from existing hatchery facilities.

*Remedial measures*

Cooperation between the State and the Federal Bureau of Fisheries in restocking is recommended.

### Arizona

*Conditions*

Actual figures not available but estimates indicate 25 per cent loss of trout. Similar estimates covering warm-water fish estimate a 50 per cent loss. Trout loss was due to drying up of smaller streams and intensive fishing. Loss of warm-water fish due to drainage of irrigation reservoirs and complete drying up of smaller lakes.

*Remedial measures*

Considerable salvage work has been carried on.

## Summary

A review of the reports supports the conclusion that the area of most serious drought damage to fish is somewhat more restricted than the extent of the drought itself. On the map, the region of most serious damage would be roughly T-shaped, with the arm of the T extending through Nebraska, Kansas, and the Dakotas eastward through Indiana, and the vertical leg reaching down the Mississippi Valley through Missouri and Arkansas. In this area there is indication of immediate, evident, and visible loss of fish. Elsewhere the damage seems to be more indirect and problematical. Deoxygenation from several different causes, intensification of pollution, destruction of food, attacks from predators and human fish hogs are cited as the means whereby water-shortage ravages the aquatic population. In several instances fear is expressed that there will be future losses due to the fish "freezing out" during the coming winter in waters reduced to low levels. In fact it is held in one case that loss of breeding stock will involve shortage of fish for several years to come. On the other hand, spring spawning seemed to be normal or above the average, due to the fact that the acute drought stage was reached later in the year.

As for remedial measures, rescue or salvage work involving transfer of stranded fish to living waters seemed to be the standby. The extent of this work was of course correlated with the funds available, and it is apparent that much of the territory where such work was needed could not be covered. It was also rendered more difficult in some cases due to weakened condition of fish exposed to high temperatures and other adverse conditions. On the other hand, careful organization of the work, utilizing the services of wardens and volunteer sportsmen enabled some States to make a good showing in spite of a lean exchequer. A review of this situation immediately prompts the thought that the setting up of contingent funds to be expended only for salvage work in years of inadequate rainfall, would be wise fisheries administration. However, under present conditions, I cannot conceive of any fish and game department permitting any sizeable piece of change to be unused gathering moss. One helpful step, however, is for the anglers to refrain from the wholesale slaughter of fish concentrated in small areas and suffering from an inadequate food supply. A limit catch of fish in drought times should merit a sportsmen's demerit badge unless the fish are clearly doomed to certain destruction anyway. Various suggestions as to the desirability of meeting the primary phase of the problem by a broad-scale program of water conservation, were made.

In 1930 there was severe drought which has been considered the low-water mark for recent years up to 1934. The Bureau of Fisheries instituted a similar survey at that time and comparison of the reports for the two years shows a striking similarity, except for geographical differences. The earlier drought was centered more to the east and south of the current catastrophe, but several States were very hard hit twice in succession. Among these were Arkansas, Kansas, Indiana, and to a lesser degree Iowa, Illinois and Nebraska. The same causes and effects were reported and Nature apparently has a standard pattern for its periodical attack upon our none too abundant stocks of fish. We will never know exactly how many fish perished during the blazing drought of 1934, but until the face of the country is changed so as to prevent drought we will probably have similar recurrences with attendant destruction. And there will apparently be little we can do about it except to rescue a pitifully small proportion and to stand in alignment with other interests, stricken by the weather, and "take it."

# THE PURPOSE AND VALUE OF STREAM IMPROVEMENT

H. S. Davis
*U. S. Bureau of Fisheries*

In the last few years we have all of us heard much about stream improvement. It is something that makes an instant appeal to the imagination and consequently there is probably no subject connected with angling and fisheries management that has received more publicity. As is so often the case when a subject receives undue publicity, stream improvement has attained an importance in the popular mind that far transcends that of any other phase of fisheries management. The average angler has come to look upon it as the answer to his fondest dreams and the open sesame that will insure a full creel any time he may choose to spend a few hours on his favorite stream.

In view of this fact I have thought it might be worthwhile to inquire into the purpose of stream improvement and what we may reasonably expect can be accomplished. As the name signifies, the object of stream improvement is to make our streams a better place for fish to live. Or, in other words, to make it possible for a stream to produce more and better fish, and the value of any form of improvement must be judged by the extent to which it will aid in producing this result.

If we attempt to analyze the purpose of stream improvement in more detail we may list its aims as follows:

1. To provide sufficient cover and shelter for the needs of the fish.
2. To prevent, as far as possible, extreme and rapid fluctuations in the volume of flow.
3. To prevent or control soil erosion and its consequent evils.
4. To increase the production of fish food.
5. To insure favorable temperatures for the species of fish to which the stream in question is best adapted.
6. To provide favorable conditions for natural propagation.

Theoretically, at least, these are, I believe, the principal objects of stream improvement. How far we shall be able to attain these ends in practice is quite another matter.

To provide cover and shelter for fish is a comparatively simple matter and probably nine-tenths of the stream improvement installations in common use have been developed for this purpose. The use of dams and deflectors to provide pools for trout is primarily for shelter. So are the various logs, rafts, and similar installations which provide very satisfactory cover and protection for the fish. There is no doubt that such installations serve a very useful purpose, and where pools and cover are deficient, tend to make a stream more attractive to trout and other game fish. It is even probable that much of the difficulty experienced in certain streams where the fish are said to disappear soon after being planted may be overcome by this method of making the stream more attractive.

But the very success of this type of improvement has its dangers. Since such installations are easy to construct they are being used in ever increasing numbers and in some instances hardly a foot of stream has been left in its original condition. Of what benefit to a stream is it to construct cover for many times the number of fish the stream can support? The number of fish which any stream can support is definitely limited by the basic food supply and no amount of enticing pools or alluring shelters can affect this vital fact.

Furthermore, I believe that, above all else, we should strive to retain the natural beauties of our streams. Anything which will lend an air of artificiality to a stream should be avoided if it is possible to do so. Such installations as are used should harmonize with the environment and be as inconspicuous as possible. There may be those who enjoy fishing in waters cluttered up with stone walls, massive dams and sundry other installations which are an abomination to the eye and a trial to the spirit, but I do not believe the true angler will derive much pleasure or satisfaction from fishing in a stream which to all intents and purposes is simply a series of rearing pools.

If it comes to a show-down, I think most of us would prefer less fish and more natural beauty, but I doubt very seriously if such a choice is necessary. As a matter of fact, I believe that simple, inconspicuous installations are just as effective in providing shelter as the more elaborate and expensive devices that are being used in so many instances. Moreover, by proper installations the appearance of a stream may in many instances be greatly improved, as when a long stretch of shallow, monotonous riffles is converted into a series of attractive pools and rapids by the construction of low dams and deflectors.

To provide a more uniform flow of water and prevent sudden and extreme fluctuations in volume is by no means as simple a matter as to furnish cover and shelter but, nevertheless, there is no doubt that much can be accomplished in this field. The most striking examples of this type of improvement are to be found in the West, especially in the High Sierras of California where large reservoirs have been formed at comparatively little expense by damming the narrow openings of natural basins. Water from the melting snows is stored in these reservoirs and allowed to flow out gradually during the summer thus maintaining a uniform flow in the streams below. This has resulted in a wonderful improvement in these streams accompanied by a striking increase in the trout population.

This type of stream improvement is, of course, closely associated with various methods of flood control and in general it may be said that anything which will prevent disastrous floods will also tend to improve the streams, provided the movements of the fish are not seriously hampered or water temperatures materially increased. With the increasing interest that is being taken in flood control and water conservation, it is inevitable that this phase of stream improvement will assume greater importance in the future.

The creation of pools by means of dams or deflectors, while not actually increasing the volume of flow during low stages, does have a similar effect since it provides a means by which fish are able to live through the dry season in streams where, otherwise, they would quickly perish.

An essential part of the problem of flood control is the prevention of soil erosion. The great quantities of soil washed into our streams during heavy rains destroy large numbers of food organisms and form shifting beds of silt and sand which are relatively unproductive. Moreover, spawing beds are ruined and eggs and fry destroyed in large numbers. There are many instances of streams, once noted for their trout, which have been ruined by accumulations of sediment resulting from the deforestation and cultivation of the adjoining land. In many cases the only remedy is reforestation which is fully as important a form of stream improvement as the building of dams or deflectors.

As previously indicated, an important feature of the control of floods and erosion is its effect on the food supply. Food organisms are even more affected by great variations in the volume of flow than are the fish. Violent floods, especially in mountainous regions, scour the bottom and destroy large numbers of these organisms while the extremely low stages found in such streams during the dry season are equally disastrous. The most favorable conditions for the production of food organisms can only be obtained where there is a fairly uniform flow throughout the year and anything which will tend to equalize the flow should have a beneficial effect on the food supply.

Aside from this, however, it is questionable if most stream improvements have a favorable effect on food organisms. On the contrary, there are good reasons for believing that much of the improvement work has the opposite result and that the total amount of available food is actually diminished rather than increased. Since P. R. Needham and other investigators have shown that insects and other organisms are more abundant in shallow riffles than in pools, it follows that a marked reduction in riffle area, which is so frequently the result of stream improvement, may be followed by a considerable decrease in the food supply. Such a reduction in the available food may be justified if, as a result of the improvements, fish are induced to live in sections where previously they did not occur. It is obvious that no matter how abundant the food may be it is of no practical value unless fish are present to make use of it. On the other hand, any reduction in the food supply diminishes, to that extent, the potential productive capacity of the stream, and it is easy to understand how the overdevelopment of pools may actually tend to reduce the fish population rather than otherwise. Thus it is that in our zeal for the building of pools there is real danger that we may do a stream more harm than good.

The available food may be increased by encouraging the development of weed beds and other aquatic vegetation but in most trout

streams the possibilties in this direction are very limited. In warmer and more sluggish streams, however, much can frequently be done to improve them in this respect.

As previously pointed out, the production of food organisms in any stream is dependent on the basic food supply, and it is more than doubtful if there is any practicable way in which this can be increased. Fertilization of streams is impractical except in connection with the deposition of sewage. Domestic sewage, if properly treated before being allowed to enter a stream, may greatly increase its productive capacity and there are doubtless many streams which have been materially improved in this way. Other methods of fertilization are too expensive since a large percentage of any fertilizer would be swept away before becoming available to stream organisms.

As everyone knows, one of the most important controlling factors in trout streams is the temperature, and there are doubtless many streams which can be improved in this respect. Many streams at high altitudes, for instance, are too cold during the short summer season for trout to grow well. The construction of dams to make wide, shallow ponds should increase the temperature and thus provide better growing conditions. The higher temperatures and increased water area should also tend to increase the food supply. At lower altitudes we have the opposite condition. Here the construction of pools may easily result in the water becoming too warm for trout.

There are many streams which due to deforestation and other factors are no longer suitable for trout. Such streams can often be again made to furnish good fishing by providing shade which will lower the temperature sufficiently to allow trout to flourish. Conserving the water supply so as to prevent extreme low stages during the summer tends to produce the same result. The construction of deflectors to narrow the channel and speed up the current will also help to keep the temperature down.

Specific aid to natural propagation is usually unnecessary since, where conditions are otherwise satisfactory, there are usually sufficient facilities for spawning and for the development of the young. In some cases, however, streams may be materially improved by diverting the current so as to expose gravel beds which have become covered with silt. Dumping gravel in the stream has also been suggested but the adoption of such expensive methods are rarely necessary.

I have considered the possibilities of stream improvement in some detail in order to show that there is little doubt that much can be accomplished in this field. On the other hand, it is equally evident that stream improvement has its limitations and that the wild and extravagant claims of some of its devotees are entirely unjustified. There is no doubt in my mind that stream improvement should occupy an important place in any well-balanced plan of fishery management, but that is no reason for allowing it to run away with the show.

There are undoubtedly many streams which do not need improve-

ment, except possibly in limited areas; there are many other streams which are not susceptible of improvement except at a cost out of all proportion to any results which could possibly be obtained. The old adage that it is best to leave well enough alone was never better exemplified than in the case of stream improvement. There are those who would "gild the lily" but it is well to remember that any attempt to do so may easily result in its ultimate destruction.

Although by no means new, stream improvement is still in the experimental stage, and there are few reliable data on which to base an estimate of its true value. The various types of installations, for instance, which will give best results under different conditions are still unknown. We do not even know, in many instances, whether the installations in common use will fulfill the purpose for which they are intended. How far these installations will be able to withstand the effects of floods and other unfavorable conditions is still, for the most part, a matter for conjecture. It is doubtful if many of them will endure for long, and it will be difficult for anyone to justify the construction of installations which must be renewed every year or two. Furthermore, there is the all-important question: How far are we justified, from an economic standpoint, in proceeding with stream improvement? Is it not possible that some of the money now being expended on this work would yield greater returns if used for the construction and maintenance of rearing pools, or for the development of a scientific stocking program based on adequate surveys and field investigations? There is remarkably little evidence to show that much of the stream improvement work will yield returns at all commensurate with its cost.

This is, I believe, a matter that is worthy of our most serious consideration. We are woefully ignorant of even the most elementary facts which would enable us to utilize our hatchery product to best advantage, and it is my opinion that some of the attention now being lavished on stream improvement might better be devoted to other problems of fishery management. There is still room for improvement in our hatchery technique and much greater room for improvement in our stocking technique. In the development of any well-balanced program of fishery management this fact must be recognized and each problem receive its proper share of attention.

# A PROBLEM IN TROUT STREAM MANAGEMENT

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The field studies of New York waters which are being carried on by the Conservation Department may be classed as extensive in scope. With a large watershed of the state to be studied each year by the Biological Survey, intensive treatment of all bodies of water is not possible. Each year, however, a number of situations arise which demand some degree of intensive and specialized study before any recommendations regarding management are possible.

Trammel Creek, a trout stream within the Mohawk watershed studied in the 1934 season, was selected for a more intensive investigation than could be given each of the many trout streams within this watershed because it presents a problem typical of many other streams. It is known as a "short trout" stream. There is an abundant supply of brook trout but these are mostly so small that there is comparatively poor angling for fish of a size above the six inch limit. Under such conditions, what type of management can be used to bring about an improvement in the yield of fish? In order to obtain information leading toward an answer to this question a study of Trammel Creek was made. This study included an evaluation of environmental conditions and a quantitative study, or census, of the fish population in a screened section of the stream. One day, July 18, was spent in making an intensive study of this one section. This information was supplemented by a more extensive study of the entire stream system.

## Environmental Conditions

Trammel Creek is located near the southern edge of the Adirondack upland. The stream is 9.2 miles in length and has five tributaries which total 5.9 miles. It arises at an elevation of 2,020 feet and joins the East Canada Creek at an elevation of 1,095 feet. The stream is predominantly of the rapid, boulder type but there are a few stretches of sluggish, alder-meadow stream with predominating sand and gravel bottom. Shade conditions are generally good. There are, however, a few cleared farmlands along the lower part.

Trout are presented in approximately five miles of the main stream in summer, according to field examinations made by the survey. The trout section extends downstream to a point approximately three-quarters of a mile above the mouth of the stream. Small trout were noted in all five of the tributaries. A pond situated at the headwaters is extremely small (three-quarters of an acre) and is shallow (maximum depth seven and one-half feet). One trout was taken here, in

a gill-net set over night, despite apparently unfavorable conditions of oxygen supply (maximum 3.2 p.p.m.).

The boulder sections of the stream afford many trout pools from eighteen inches to three feet deep, with good shelter under the large boulders. There are frequent stretches of boulder shallows without good pools.

Conditions for the reproduction of brook trout are excellent. Gravel and well-aeriated spring water of favorable temperature to allow safe wintering of the eggs are factors of importance in allowing successful reproduction.

Temperature data indicate that Trammel Creek is not a stream of the coldest type; in fact, temperatures over much of the stream course are close to the maximum for brook trout and the lower part of the stream is unsuitable because of high temperatures.

TABLE 1. HOT WEATHER TEMPERATURES IN TRAMMEL CREEK

| Station | Temperature Air | Temperature Water | Time (p. m.) | Approximate altitude | Trout present |
|---|---|---|---|---|---|
| 0.5 mile above mouth | 87.5 | 79.0 | 5:50 | 1,135 | |
| 1.8 miles above mouth | 86.5 | 77.0 | 5:15 | 1,360 | X |
| 2.5 miles above mouth | 86.5 | 74.5 | 4:45 | 1,460 | X |
| 3.5 miles above mouth | 86.0 | 76.5 | 4:15 | 1,525 | X |
| *3.6 miles above mouth | 76.0 | 66.5 | 3:10 | 1,530 | X |
| 5.5 miles above mouth | 71.5 | 70.0 | 7:40 | 1,645 | |

NOTE: First four temperatures in table taken July 20; fifth, July 18; sixth, July 12. When indicated as present trout were seen or taken at the time temperatures were taken.
*Census station.

Six chemical analyses of Trammel Creek indicate that in the vicinity of the seining station mid-day temperatures of 59.36-61.16° F. at an air temperature of 75.92° F. and excellent gaseous relationships prevail. The carbon dioxide content is low (2.0-3.0 p.p.m.) and the oxygen values approach saturation (92.0-93.8 per cent). The water is slightly acid in reaction (pH 6.7-6.9) while the low alkalinity of 17.0 p.p.m. is more typical of Adirondack drainage than that of the adjacent Mohawk area. As the creek proceeds to its outlet into East Canada Creek, the water becomes alkaline (pH 7.1-7.5) with the alkalinity increasing to 24.0 p.p.m. The oxygen values remain high (92.2-104.2 per cent saturation).

## History of Fish Management

A program of stocking Trammel Creek with brook trout was started by local sportsmen with the belief that the introduction of "new blood" would increase the size of the fish. According to Conservation Department records, Trammel Creek has been stocked, during the last ten years, with 18,525 brook trout. This is an average of 1,852 per year, and is at the rate of about 370 fish per mile for the five miles of trout water. In the tributaries 2,400 brook trout have been stocked in the same period, or an average of 240 per year. Compared with

stocking ordinarily recommended for waters of similar size, pool, and food valuations this represents a very light stocking.

## Quantitative Study of the Fish Population

The choice of a section of the stream for quantitative studies was dictated largely by physical conditions, which were unsuitable for this type of work over most of the stream course. Seining was practically impossible in the boulder sections. A part of the stream in the beaver-meadow region offered comparatively favorable conditions. Seines were stretched across the stream here, setting off a section 210 feet long. Most of the obstructions were removed and the screened area was then seined with six-foot minnow seines. After approximately three hours of work, with two seines in use, the area was rather thoroughly cleared of fish. It was estimated that at least 90 per cent of the fish were removed.

The stream at this point (Fig. 1) was from 14 to 20 feet wide and had an average width of 17 feet. The depths ranged up to 3 feet. At least 50 per cent of the area was over one foot deep. There were four deep pools, two of them 3 feet deep and two of them 2 feet deep. A large boulder, a log, numerous water-logged sticks, and top cover of alder clumps offered excellent shelter conditions. There were several undercut banks under the alder roots. The bottom was predominantly sandy gravel (estimated as 50 per cent). Sticks and other detritus made up about 20 per cent of the bottom, silt and organic muck comprised approximately 20 per cent, and large boulders (in lower end of the area) made up approximately 10 per cent of the bottom. Only approximately 15 per cent of the bottom surface was covered by aquatic plants. *Fontinalis* moss was the predominant one of the five species of plants collected here. The current velocity was moderate. The faster current was estimated at ½ foot per second. Some areas of slack water, behind obstructions, were present but elsewhere there was a perceptible current (at least 1/10 foot per second).

Provided that the area selected for study is typical of average conditions, the number of fish found within the 210 foot sample can be used to calculate the number of fish per mile or per acre. In using the results of a single sample for such calculations it should be held in mind that computations are subject to error conditioned by the degree by which the sample deviates from the average. We consider the region studied to be slightly better than average in conditions. There are, however, some parts of the stream which afford even better places for trout than the one selected. Angling, with artificial fly, showed that trout were very numerous in some of the better parts of the boulder region (Fig. 2).

It is of interest to note that fish quickly moved into the area which had been cleared of fish. Seining here on July 23 indicated that trout, horned dace, and black-nosed dace were again abundant, having migrated in from other parts of the stream. This observation reflects the

Fig. 1
BEAVER-MEADOW SECTION OF TRAMMEL CREEK

Fig. 2
BOULDER SECTION OF TRAMMEL CREEK

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fact that other parts of the stream were supporting a heavy fish population.

It is probable that most of the trout encountered during seining operations in Trammel Creek were fish which resulted from natural reproduction. Since no stocking was done in the 1934 season, prior to the investigation, it is obvious that young trout of that year's hatch were wild fish. Older fish were, of course, of uncertain origin but reproduction is so obviously successful in this creek that there is strong probability that most of the older fish were from natural reproduction.

The total number of fish removed from the area was 695. The species were brook trout (*Salvelinus fontinalis*), black-nosed dace (*Rhinichthys atronasus*), horned dace (*Semotilus atromaculatus*), and common bullhead (*Ameiurus nebulosus*). The weight of these was 3,531 grams. In addition to fish, there were two green frogs (*Rana clamitans*), 33.6 grams; two frog tadpoles (*Rana sp.*), 10 grams; three newts (*Triturus viridescens*), 10.2 grams; one two-lined salamander (*Eurycea bislineata*), 0.2 grams; and twenty-one crayfish (*Cambarus bartonii*), 169.3 grams. Organisms other than the fish were collected as incidental to the seining of the fish. They are mentioned because of their possible effect on the fish population as competitors for food.

TABLE 2. FISH COUNTED IN 210-FOOT SAMPLE AREA AND COMPUTATIONS BASED ON SAMPLE

| | Number in Sample | Weight in grams | Size range in mm. | Number per mile | Number per acre | Weight per acre in lbs. |
|---|---|---|---|---|---|---|
| Legal-sized brook trout | 2 | 80.4 | 153-169 | 50 | 24 | 2.1 |
| Under-sized brook trout | 196 | 2,260.6 | 37-149 | 4,928 | 2,398 | 60.8 |
| Black-nosed dace | 447 | 1,053.2 | 32-97 | 11,238 | 5,455 | 28.3 |
| Horned dace | 47 | 197.4 | 41-122 | 1,182 | 574 | 5.3 |
| Common bullhead | 3 | 39.4 | 88-108 | 75 | 37 | 1.0 |
| Total | 695 | 3,531.0 | 32-169 | 17,472 | 8,482 | 97.5 |

Comparing the Trammel Creek computations with similar figures for trout streams of the Raquette watershed (Raquette Survey Report, p. 69), we find that, in total poundage of fish, Trammel Creek is fourth in the series of eight determinations. In poundage of trout, Trammel Creek is second in rank.

## Quantitative Study of Food Present

A quantitative study of invertebrate bottom organisms present in the 210-foot census area was made on the basis of seven square-foot samples. All organisms large enough to be retained by a screen of 20 meshes to the inch were counted and weighed. The average weight of the samples was 2.05 grams (the minimum was 0.5 grams from an area with only a thin coat of leaves covering a silt floor; the maximum was 6.16 grams from an area covered with a thick layer of sticks and dead leaves and with a gravel substratum). If each of the square-foot areas was typical, it should be possible to determine the total

quantity of fish food material present within the 3,570 square feet of stream. The computed total, based on these samples, was about 7,500 grams, or 16½ pounds. This is at the rate of 206 pounds per acre, a figure that indicates a relatively rich stream as compared with others studied during the same season.

A study of the insects in the square-foot samples indicated that 46.5 per cent by weight were mayflies (chiefly *Hexagenia*); 32 per cent dragonflies; 16.5 per cent caddis-flies; 1 per cent alder-flies and fish-flies; 1 per cent stoneflies; and 3 per cent miscellaneous, chiefly flies and beetles.

## Food Relations of the Fish

The question of competition for food among the fish associates in the 210-foot census was also given attention. Such inquiry, limited to a study of the diet for July 18 only, was directed mainly to a consideration of the following: Did the four species represented eat much of the same thing? Was the competition among them immediate?

For convenience in the consideration of the food habits by species, the items in the stomach contents of the brook trout, horned dace, black-nosed dace and bullhead are summarized in tables 3 to 6 inclusive, with the items shown in percentages of each type of food taken.

As would be expected from the known food habits of the trout, a high percentage of food in its diet derived from organisms of terrestrial and aquatic origin became available to the trout as surface drift. This percentage for the trout was 26.55 per cent, a percentage nearly twice that of the horned dace and about fourteen times that of the black-nosed dace. The bullhead content showed no drift organisms.

It is in the consumption of aquatic food that immediate competition is greatest. In each of the five species of fish the chief staples were mayflies and dipterans.

Among the numerous items making up the aquatic food of the competitor species it is clear that the high consumption of larval forms must operate to cut down appreciably a supply of food that later would become available to the trout as drift food. In this respect competition which may not appear to be serious because it is not immediate, becomes so ultimately through the reduced supply of transforming aquatic life.

It was obvious by contrast that the trout appeared less well fed than their competitors, which were plump and fat. The more roving forage habits of the dace and bullheads, seeking food where it may be found rather than accepting what may be brought by the current, naturally results in a greater percentage of the food being taken by them than by trout. Large trout which might feed upon these competitor species are largely removed by angling.

Of the 42 recognized genera of insects obtained in the bottom samples and supplementary collections, nearly all were represented in the food taken by the fishes.

TABLE 3. SUMMARY OF KINDS OF FOOD EATEN BY BROOK TROUT IN THE CENSUS AREA

(Percentages computed by estimating the volume of each item in the stomachs of each of 117 trout)

| AQUATIC FOOD | Average (Per cent) | SURFACE DRIFT | Average (Per cent) |
|---|---|---|---|
| Mayfly nymphs (Hexagenia and others) | 18.33 | Dipteran adults (empidid flies chiefly) | 6.25 |
| Insect debris | 16.39 | Insect debris | 4.23 |
| Dipteran larvae and pupae (midges chiefly, craneflies, etc.) | 16.19 | Beetles | 3.18 |
| Caddis larvae, pupae, and cases | 13.38 | Caddisflies | 3.02 |
| Odonate nymphs (damselfly and dragonfly) | 3.14 | Lepidoptera (butterflies, moths, and caterpillars) | 2.55 |
| Beetle larvae | 2.58 | Spiders | 1.82 |
| Stonefly nymphs | 1.32 | Ants and ichneumon flies | 1.70 |
| Plant fragments (seeds chiefly) | 1.30 | Stoneflies | 1.59 |
| Fish (black-nosed dace fry) | .42 | Bugs (leafhoppers chiefly) | 1.02 |
| Bugs | .37 | Mayflies | .81 |
| Cladocera and mites, trace | .03 | Odonates (dragonflies and damselflies) | .38 |
| Total | 73.45 | Total | 26.55 |

| | |
|---|---|
| Aquatic food | 73.45% |
| Surface drift | 26.55% |
| Total | 100.00% |

TABLE 4. SUMMARY OF KINDS OF FOOD EATEN BY HORNED DACE IN THE CENSUS AREA

(Percentages computed by estimating the volume of each item in the stomachs of each of 41 horned dace)

| AQUATIC FOOD | Average (Per cent) | SURFACE DRIFT | Average (Per cent) |
|---|---|---|---|
| Mayfly nymphs (Hexagenia and others) | 29.83 | Lepidoptera (butterflies, moths, and caterpillars) | 7.80 |
| Insect debris | 16.14 | Insect debris | 2.23 |
| Dipteran larvae and pupae (midges chiefly) | 13.88 | Caddisflies | 1.71 |
| Odonate nymphs | 12.93 | Dipteran adults (empidid flies and others) | 1.10 |
| Crustacea (crayfish and eggs) | 4.03 | Beetles | .73 |
| Caddis larvae | 4.02 | Spiders | .49 |
| Beetle larvae | 2.32 | Ants | .10 |
| Sialis larvae | 2.32 | | |
| Plant fragments | .37 | | |
| Total | 85.84 | Total | 14.16 |

| | |
|---|---|
| Aquatic food | 85.84% |
| Surface drift | 14.16% |
| Total | 100.00% |

TABLE 5. SUMMARY OF KINDS OF FOOD EATEN BY BLACK-NOSED DACE IN THE CENSUS AREA

(Percentages computed by estimating the volume of each item in the stomachs of each of 121 black-nosed dace)*

| AQUATIC FOOD | Average (Per cent) | SURFACE DRIFT | Average (Per cent) |
|---|---|---|---|
| Dipteran larvae and pupae (midges and craneflies chiefly) | 52.23 | Dipteran adults | 1.11 |
| Mayfly nymphs (Hexagenia and others) | 21.18 | Insect debris | .09 |
| Insect debris, grit, sand, etc. | 10.58 | | |
| Caddis larvae | 4.81 | | |
| Algae | 3.55 | | |
| Beetle larvae | 2.54 | | |
| Odonate nymphs | 1.94 | | |
| Worms | 1.28 | | |
| Gammarus | .69 | | |
| Total | 98.80 | Total | 1.20 |

| | |
|---|---|
| Aquatic food | 98.80% |
| Surface drift | 1.20% |
| Total | 100.00% |

*100 of the black-nosed dace were examined by Dr. W. J. Hamilton of Cornell University.

TABLE 6. SUMMARY OF KINDS OF FOOD EATEN BY BULLHEADS IN THE CENSUS AREA

(Percentages computed by estimating the volume of each item in the stomachs of each of 3 bullheads)

| AQUATIC FOOD ONLY | Average (Per cent) |
|---|---|
| Mayfly nymphs | 49.00 |
| Debris and grit | 25.67 |
| Dipteran larvae (midges chiefly) | 12.67 |
| Mollusca (sphaerium) | 8.33 |
| Beetle larvae | 2.67 |
| Plant fragments | 1.33 |
| Crustacea (Cladocera) | .33 |
| Total | 100.00 |

Aquatic food ........ 100%

## Growth Rate of Trout

A study of the rate of growth of trout taken during the seining of the 210-foot area, together with supplemental collections made at this and other parts of the stream, was carried on by means of scale examinations. Scale samples were mounted on glass slides and were studied with a binocular microscope.

The nature of the annulus formed on brook trout scales has been discussed by Hazzard (1932). The Trammel Creek specimens of the older fish had rather clearly-defined annuli, for the most part. Brook trout scales, however, sometimes have very little structure to indicate where the growth of one season ends and that of the next season begins. It is possible that a few scales might have been read as one year too young, through missing the first annulus. It is improbable that errors in the other direction occurred.

Scale samples from 157 trout from the series of 198 fish taken in the quantitative seining were studied. A series of 19 trout, taken in the boulder section of the stream 1½ miles below the census area (July 4); a series of 7 fish also from the same boulder region (July 15); and a series of six individuals also from the same section (July 18), are included. These fish were taken by angling. In seining on July 23, at the exact spot where the quantitative seining was done on July 18, twenty trout were taken for growth only. In the accompanying table fish from the boulder section are designated by the letter A and fish from the census station are designated by the letter B.

In interpreting the figures given in the table, it should be recognized that averages are doubtless affected by the varying numbers of fish taken on the several dates. Trout taken July 23, for example, had nineteen more days in which to grow than those taken on July 4. Three individuals of the one annulus group of the July 18 (B) series were excluded as sexes were not determined. These fish averaged 79 millimeters. Forty-one individuals of the same series of specimens were excluded from the table because, through oversight, scale samples were not taken. From the measurements of these individuals, they were mostly fish of the two annulus group.

**TABLE 7. TOTAL LENGTHS IN MILLIMETERS AND AGES OF TROUT**

**(Legal length 6 inches, equals 152.4 millimeters)**

| Date | | 0 ANNULUS No. | Ave. length | Range | 1 ANNULUS No. | Ave. length | Range | 2 ANNULI No. | Ave. length | Range | 3 ANNULI No. | Ave. length | Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/4 (A) | M | 0 | .... | ........ | 3 | 102 | 100-105 | 6 | 119 | 107-137 | 1 | 184 | ........ |
| | F | 0 | .... | ........ | 1 | 105 | .... | 7 | 124 | 100-148 | 1 | 130 | ........ |
| 7/15 (A) | M | 0 | .... | ........ | 2 | 84 | 78-89 | 0 | .... | ........ | 0 | .... | ........ |
| | F | 0 | .... | ........ | 0 | .... | ........ | 5 | 98 | 94-106 | 0 | .... | ........ |
| 7/18 (A) | M | 0 | .... | ........ | 2 | 122 | 118-126 | 0 | .... | ........ | 0 | .... | ........ |
| | F | 0 | .... | ........ | 2 | 111 | 99-122 | 2 | 136 | 135-137 | 0 | .... | ........ |
| 7/18 (B) | M | | | | 39 | 90 | 74-102 | 14 | 134 | 118-146 | 0 | .... | ........ |
| | *J | 29 | 50 | 35-58 | | | | | | | | | |
| | F | | | | 36 | 90 | 73-101 | 35 | 128 | 102-169 | 1 | 153 | ........ |
| 7/23 (B) | M | | | | 5 | 89 | 77-103 | 3 | 116 | 111-123 | 0 | .... | ........ |
| | *J | 2 | 57 | 54-60 | | | | | | | | | |
| | F | | | | 6 | 90 | 81-107 | 4 | 125 | 117-131 | 0 | .... | ........ |
| Total | M | | | | 51 | 92 | 74-126 | 23 | 128 | 107-146 | 1 | 184 | ........ |
| | *J | 31 | 51 | 37-60 | | | | | | | | | |
| | F | | | | 45 | 92 | 73-122 | 53 | 125 | 94-169 | 2 | 142 | 130-153 |

*J—Juvenile. Sex was not determined in these smaller fish.

In the large July 18 collection, it is perhaps significant to note that there were more females than males among the larger individuals. Considering only those of 100 millimeters or above, predominantly fish of the 2 annulus group, there were 65 females and only 29 males, over twice as many females as males. The sex ratio of the one annulus group in this series is close to the expected 50:50 proportion. According to the age determinations of the 2 annulus group, males grow slightly faster than females. Our data, although insufficient for a detailed study of this aspect of the life-history of brook trout, suggest that a study of the differential growth-rate of wild trout might throw some light on the matter of the upset in the sex-ratio among the older fish. If the males, on the average, reach the six-inch legal size earlier than the females, it would be expected that more males than females would be removed by angling.

The most significant point shown by study of the growth rate of the Trammel Creek trout is that the fish are conspicuously slow of growth as compared to the maximum for trout under hatchery conditions. Many hatchery-reared trout will exceed six inches by the end of the first growing season, whereas none of the Trammel Creek trout would attain legal size at the end of the first season. Probably few would be six inches or over at the close of their second season. In fact, only one of the Trammel Creek trout of the two annulus group (representing fish with two full growing seasons and a good fraction of a third) is above six inches. Under favorable conditions, wild fish will far outstrip the growth made by these trout. For example, four brook trout (three females and one male) taken in Bochen Lake of the Mohawk watershed on June 30, 1934 at an age of two annuli averaged 209 millimeters long (the range was 203 to 213 mm.). Weights of these

fish were not taken, but applying the weight-length curve given for brook trout by Hazzard (1932) it is apparent that the Bochen Lake fish would weigh nearly four times as heavy as the average of the Trammel Creek fish of the same year class.

The time of year at which the collections were made is not favorable to ascertaining, with certainty, the percentage of fish which would be mature for the 1934 breeding season. Even as early as the July date of capture, however, there was conspicuous enlargement of the reproductive organs of quite a large number of individuals among the one-annulus group and older groups. The smallest of the females having very large eggs was 104 millimeters. The size of the smallest mature females of brook trout is a fairly good index of local growth conditions, since female brook trout do not ordinarily mature before the end of the second growing season.

## Suggested Methods for Management

The study of Trammel Creek has indicated that this stream is rather productive of fish life, but that comparatively few fish of legal size are present. Growth rate of the trout here is poor as compared with growth under hatchery pond conditions or under conditions which obtain in certain other wild waters.

Possible factors concerned as causes for poor growth rate include water temperature, food supply, and inherent capabilities of the stock. Water temperature affects rate of food consumption and low temperatures retard growth, a fact familiar to fish culturists. The effect of low water temperatures on growth of wild trout is discussed by Hazzard (1933). The amount of food consumed by each individual is an obvious factor in affecting growth. Inherited tendencies toward stunting or toward accelerated growth are known to be important. The recent development of selected strains of fast growing trout has indicated the influence of inherited trends. (Embody and Hayford, 1925.)

It is impossible to evaluate exactly these three growth factors in their effect on the Trammel Creek trout. All of these may have some effect. It is advisable, however, to go as far as possible in evaluation of which are the most significant causes for poor growth rate.

Water temperatures of Trammel Creek are by no means extremely low. In fact, part of the stream is even too warm for trout. There must be, between the extreme ranges of temperature in this creek a zone of optimum temperature—cold enough to be trout water but warm enough to allow rapid digestion of food. However, no zone of rapidly-growing trout was observed, even though collections were made within a short distance of the lower limit of trout, as water temperatures of as high as 77° F.

The inherent capabilities of the native stock of brook trout from Trammel Creek are not known. It is possible that there is here a

naturally stunted race of trout, or a race which has become selected for poor growth rate by generations of exposure to angling, which removes only the larger fish. No experimental study of the capacity of these fish to grow has been made. If, however, the stocking of this stream with apparently normally growing hatchery fish has had any effect on the wild population, we might expect that the trout would have the capability of making better growth than they do under present conditions. It seems improbable that the Trammel Creek fish are making the most rapid growth that they are inherently capable of doing.

The amount of food consumed by each individual is regarded as a very important factor affecting growth of these fish. The amount of food taken by a wild trout is governed by several conditions. The food must be produced, either by the stream or land, and various streams differ in food-producing capacity. The availability of food organisms is another factor of importance. An unknown percentage of the foods which are produced escapes capture by fish. The percentage of aquatic insects or other food organisms which is available to fish life doubtless differs in various streams. The amount of food eaten by each individual obviously represents that fraction of the available food that he has succeeded in catching. The competition of his own kind and other habitat mates having the same food habits is an important factor in governing the size of this fraction.

Circumstances of the Trammel Creek situation point to competition as the most obvious cause of the poor growth rate of the trout. With dozens of trout and competing species of minnows occupying each of the pools in this small stream, it is not to be wondered at that the food is cut too many ways to allow any one fish to make a maximum growth.

The poundage of fish (97.5 pounds per acre) indicates that this stream has the capacity to produce rather well. The fact that the majority (62.9 pounds per acre) are trout indicates that this stream is a biologically productive trout stream. That legal trout were present at the rate of only 2.1 pounds per acre can be considered indicative of a badly balanced condition that makes this stream a relatively unproductive angling stream. As a management problem, there is much to work with in a stream of this type, for the total productivity is so much higher than the productivity of legal-sized fish that one may expect to obtain excellent results from management practices aimed at regulating the fish population to a more favorable balance of the ratio of legal-sized trout to other fish. Without changing the total fish production, why cannot this stream be balanced so as to contain 50 of its 97.5 pounds per acre in the form of legal-sized trout instead of the present computed figure of 2.1 pounds?

To do this in Trammel Creek or similar streams is going to take a new and more intensive type of management than has yet come into general use. As streams become more thoroughly studied, it is probable that ways of managing them, adapted to the needs of particular cases,

will be devised and carried out, to great advantage of the fisheries concerned.

Wherever fishing is unsatisfactory, the usual practice has been to turn to stocking as a cure-all remedy, on the reasoning that poor fishing must be due to lack of fish. A generally accepted, and in many cases fallacious assumption has been that there is a very heavy loss in the young of fish and that tiding over this critical period by means of fish culture would result in many more fish growing to a size of importance to the fisheries than would otherwise be possible. It can be definitely stated that stocking of small fish in a stream having conditions such as Trammel Creek is a waste of fish, time and money. Furthermore, such stocking is likely to aggravate the condition of poor growth rate by increasing the pressure on the food supply.

Stocking of legal-sized fish appears to be a favorable line of management for Trammel Creek. Some favorable considerations are that planting large fish would add to the supply of fish immediately available for angling, that large fish might find, in the form of minnows and small trout, a food supply at present largely unutilized because of the small size of the trout present in relation to the size of these food organisms, and that large fish might serve to decrease food competition among the fish which they did not succeed in catching. Some unfavorable considerations are that of expense in stocking large fish, and the limited capacity of the stream to shelter and feed many fish of large size.

If we accept competition of a large fish population as the principal cause of the slow growth rate of the trout in Trammel Creek, it seems logical to suggest that the fish population be thinned out just as lettuce plants or pine plantations are thinned out to prevent overcrowding and a resultant crop of stunted plants. While biologically sound, a direct thinning of the population in a trout brook is not always sound as a practical means for management. The extreme difficulty of catching fish with a seine in the boulder sections, heavy labor costs and mechanical disturbance to stream conditions all make direct removal of fish impractical. If the size limit on trout were to be reduced, one might expect anglers to thin out the small fish. Theoretically this measure might do some good, but there are many reasons for considering it to be impractical. Removal of size limits in certain streams would be difficult to obtain, would make a complex enforcement problem for the other streams, and would not be efficient in thinning trout except those of large enough size to take a hook.

A simple and very promising line of management of the trout population designed to thin down the number of fish is that of giving special protection to large trout. Under present conditions, the entire stream is heavily fished and large trout are scarce, as already mentioned. It is probable that the intense competition for food makes trout rather easy to catch and that most fish of legal size are removed soon after they pass the six-inch mark. Some of the larger fish may migrate down-

stream into East Canada Creek, although there was no evidence that many trout were in this creek during July, when water temperatures were unfavorable. A well-balanced number of large trout would, probably, serve to thin out the minnows and small trout, restoring conditions favorable to a more rapid growth of the small trout. The large fish could be expected doubly to improve angling conditions, not only by favoring rapid growth of small trout but also by converting excess small trout and minnows into the form of trout of desirable size. It would seem biologically sound to set aside a rather large section of the stream as a sanctuary or refuge area, closed to angling, so that some large trout would be continually present. Whether or not this would be a practicable measure, due to difficulties in changing regulations, obtaining permission from land owners, getting public cooperation, and overcoming other difficulties is uncertain.

Environmental improvement offers favorable means for attacking the problem. Many of the shallow areas of this stream are inadequate to shelter large trout. Pool improvement, especially by means of boulder dams, deflectors and removal of boulders to make pools deeper, could be made to decrease habitat conditions for small fish and to increase habitat conditions for larger fish. This has the advantage of being a relatively permanent correction of unfavorable conditions. The Civilian Conservation Corps has been doing a large amount of this type of stream improvement in New York waters bordered by state-owned lands. Improvements on the greater part of the stream mileage of New York waters, however, involve private rights of land ownership and are excluded from consideration as projects to be undertaken with C.C.C. labor.

Problems of the type represented by Trammel Creek indicate that fish management has not yet progressed to a stage which permits regulation of all those conditions obviously in need of regulation. It is only part of the task to discover what factors are limiting fish production. It is not the purpose of a field survey to accomplish changes, such as have been indicated as desirable. To correct unfavorable conditions in this brook, a well-organized program of management will need to be carried out by sportsmen's organizations, landowners or others who have the power to improve conditions. Until such a program is organized, the only immediate effect of a biological investigation is to show that stocking of small fish under these conditions is useless and can be eliminated, releasing this portion of the product of the hatcheries to be put to better advantage elsewhere.

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## Discussion

Mr. H. C. Markus (New York): I carried out a little experiment in the vicinity of Rochester, New York, that might help to supplement Dr. Moore's question of heredity. In the month of May I liberated a number of brook trout in one of the upper streams of the Cohocton river. Three months later we went back to that river and caught some of these fish—we had them marked. They had gained from one-half to three-quarters of an inch, while their brothers and sisters in the hatchery had attained a length of ten inches.

Mr. Langlois (Ohio): I wonder if by any chance Dr. Moore has seriously considered the possibility of artificially feeding the fish in that particular length of stream as you would the fish in the hatchery. If it could be done for a single season, perhaps you could raise a large percentage of the small fish already present to a better size.

Dr. Emmeline Moore: I think Dr. Greeley might answer that question.

Dr. Greeley: It is a very sound idea, judging from all the facts in the case. The only problem there is the practicability, and cost.

Mr. Cook (Michigan): Mr. E. R. Hewitt, on the Neversink river in northern New York, has done considerable work in stream feeding, and has actually some devices developed which operate by the use of a paddle wheel to distribute food to the fish in the stream. He has also put on the market, I believe, a diet which can be bought at around seven to eight cents a pound, which he recommends for the feeding of wild fish.

Dr. Belding (Massachusetts): I have looked at Dr. Moore's chart; and if you can rule out the question of the two-year fish being a fair sample because of the larger ones being possibly taken by anglers, you have a rather peculiar condition. The growth, instead of continuing in the ratio that it should, is falling off at the time the trout are about four inches long. If that were due to heredity you probably would have a consistently slow growth; therefore I am inclined to believe, assuming the sample of these older fish in size is correct, that you have some condition in the stream that is detracting from the growth of the fish at four inches.

Dr. Greeley: I think that is very likely. The intensity of competition of fish about that size is very great. The ones bigger than that are removed, and the ones smaller than that do not eat so much food per individual and do not crowd up so badly. The bad crowding in that sample is in the four or five-inch trout.

# THE PROBLEM OF STREAM POLLUTION IN TEXAS WITH SPECIAL REFERENCE TO SALT WATER FROM THE OIL FIELDS

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## INTRODUCTION

The Game, Fish and Oyster Commission of Texas is charged with the enforcement of the anti-pollution laws is so far as pollution affects the aquatic resources of the State. A major source of pollution in Texas is the salt water from the oil fields. Since a major oil field exists on practically every important watershed in the State, this problem is one of considerable magnitude. Much of the trouble in this connection arises from abandoned wells. It is a characteristic of oil wells in Texas that they ultimately turn to the production of salt water. The small independent operator, often inadequately financed, causes more trouble and damage than the larger operators.

This paper will be restricted to the presentation of certain facts with reference to the effects of salt water and will not consider the pollution resulting from the crude oil itself.

## METHOD OF DISPOSAL OF SALT WATER

Operators, if left to follow their own course, will naturally discharge the salt water into any body of water that is conveniently located. This is done without any reference to the amount of water available to dilute the salt water . The Game, Fish and Oyster Commission recommends that the salt water be impounded in resorvoirs and that it be discharged from these reservoirs at such a rate that it will not affect fish life adversely. This method can best be illustrated by a reference to the Palestine Oil Field in East Texas. Here the salt water from the entire field is piped into a small pond. The oil gathers on the surface and is skimmed off or burned. The water is drained off at the bottom and collects in a second pond (about 20 acres). Some oil still gathers on the surface of the salt water in this pond. Finally the water passes under a series of baffles into a third pond (about 20 acres). From this pond the water is discharged through a small creek into the Neches River. The discharge occurs only when the latter river is at high-water stage. How completely the discharge from this field is controlled may be gathered from the following facts: A sample of water from this field analyzed by the State Chemist, Dr. G. S. Fraps, showed as follows: $CaCO_3$ 135 p.p.m., $CaSO_4$ 165 p.p.m., $CaCl_2$ 5,744 p.p.m., $MgCl_2$ 1,691 p.p.m. and NaCl 71,564 p.p.m. or a total salinity of 79,299 p.p.m. At times this water has a total salinity of around 91,000 p.p.m. or nearly three times the salinity of the Atlantic Ocean. At Beaumont about 100 miles below where this salt water

enters the Neches River the water from the latter is used for irrigating rice fields.

The method of impounding the salt water, as recommended by the Commission, has been a complete success in the Palestine Field. No complaints have come from this section of the State for several years. This condition has been achieved without recourse to law. In another important oil field where the average total salinity is only approximately one-third of that in the Palestine Field, methods of persuasion have failed. Only a year ago the river into which this field discharged was completely sterilized, as far as fish are concerned, from a point where the salt water enters the river to the mouth of the river. A court injunction has remedied this situation. The Texas Anti-pollution Law makes such action possible. It states that no one shall be permitted to artificially raise the total salinity of a stream above 2,000 p.p.m. This limit is set by law in spite of the fact that some Texas streams naturally have a salinity of around 5,000 p.p.m. or 2½ times that permitted by law.

The water from the Palestine Field probably ranks highest in salinity. According to an analysis furnished us by Mr. W. B. Wardlow the water from the Luling Field has the following composition: $Ca(HCO_3)_2$ 770 p.p.m., $CaSO_4$ 910 p.p.m., $CaCl_2$ 3,190 p.p.m., $MgCl_2$ 1,000 p.p.m., and NaCl 30,150 p.p.m., or a total salinity of 36,020 p.p.m. The Luling field does not cause any trouble because the salt water from this field is discharged into a relatively large body of water which causes sufficient dilution to make the effluent harmless.

## Effect of Salt Water on Fish

The effect may be (1) increase in osmotic pressure and (2) a direct toxic effect. The osmotic pressures that fish can tolerate depends to a large extent on acclimatization. That fish can become acclimated to fairly high salinities is shown by the presence of certain species of fresh water fish in brackish water as well as by the fish fauna in such streams as the Pecos River in West Texas. Fish existing under these conditions could probably tolerate an appreciable increase in salinity without suffering. However, fish acclimated to the extremely soft waters of East Texas cannot survive when suddenly subjected to salinities such as occur in the Pecos River or that result from the addition to the streams of large quantities of salt water from the oil fields. These are points to be considered in experimenting with fish.

## The Salinities of Some Texas Rivers

The following figures give some ideas of the difference in the water of some Texas rivers: Angelina River (extreme east) $MgCO_3$ 16 p.p.m. (no Ca), NaCl 29 p.p.m. and pH 6.8; Neches (far east) $CaCO_3$ 16 p.p.m., $MgCl_2$ 17 p.p.m., NaCl 15 p.p.m. and pH 7.0; Trinity (east) $CaCO_3$ 130 p.p.m., Chlorides (?) 124 p.p.m., and pH

7.6; Brazos (central) large amount of $CaSO_4$, and chlorides 1,000 p.p.m., pH 8.4; Colorado (central) $CaCO_3$ 145 p.p.m., $MgCO_3$ 25 p.p.m., $MgSO_4$ 48 p.p.m., $MgCl_2$ 30 p.p.m., NaCl 82 p.p.m., and pH 8.5; Pecos (far west) $CaCO_3$ 150 p.p.m., $CaSO_4$ 1,156 p.p.m., $MgSO_4$ 480 p.p.m., $Na_2SO_4$ 333 p.p.m., NaCl 2,691 p.p.m. and pH 8.6. The Pecos has a total salinity of 4,810 p.p.m. (These analyses have been made by Mr. W. B. Wardlow and Dr. E. P. Schoch.) These figures emphasize the great difference in salinity of different Texas rivers. They also show that the streams of East Texas where most of the salt water is produced contain naturally very little salt.

## Experimental

Mr. Burr found that in water from the Luling Field containing 1,230 p.p.m. of salt (for composition of water from Luling Field see page 82) one adult bass died of fungus in 8 days, another lived 23 days, and a third survived indefinitely; in 2,000 p.p.m. one adult bass survived and another died in 8 days with fungus; in 3,890 p.p.m. one bass died in two days and the second in five days, both from fungus; in 13,100 p.p.m. a bass died in 21.5 hrs. and a white crappie in 55 hrs. from the sole effect of salt. These results did not check with the results obtained by Marsh (U. S. Bur. of Fish. memorandum I-33), who found that seawater of sp.gr. 1.010 (14,000 p.p.m.) failed to kill either perch or bass in 14 days. The difference in the effect of seawater containing 14,000 p.p.m. salt and the Luling water containing 13,100 p.p.m. salt was no doubt due to the difference in the composition of these two waters. Sea water contains in addition to sodium chlorides considerable quantities of magnesium chlorides but no calcium chlorides, whereas 9 per cent of the salt in the water from the Luling Field was calcium chloride and 2.77 per cent magnesium chlorides. Weigelt (1885—U. S. Bur. Fish. I-33) found that a 1 per cent (10,000 p.p.m.) $CaCl_2$ caused distress to tench (*Tinca vulgaris*) after 3 hrs. at 20° C. which died 3 days later in fresh water. From this it is apparent that $CaCl_2$ is much more toxic than an equal concentration of NaCl. That this is the case will also be shown by new data in the pages that follow. The difference in the results obtained by Mr. Burr and Dr. Marsh may, therefore, be accounted for by the presence of $CaCl_2$ and $MgCl_2$ in the water used by Mr. Burr.

During the last winter one of us (Wiebe) was able, through the generous co-operation of Dr. F. C. Gieseke, director of the Engineering Experiment Station at Texas A. & M. College at College Station, to organize a laboratory for experimental research on the effect of salt water on fish. Unfortunately not much could be accomplished last winter. This work, however, will be resumed this fall and it is hoped that some tangible results will be obtained. A few observations made this past winter might be of interest to conservationists and they will, therefore, be reviewed briefly.

The primary object so far has been to determine the survival time

for various species of fish in known concentrations of the separate salts that may occur in the salt water from the oil wells.

The method employed was as follows: The requisite amount of the salt was added to distilled water. To this was added sufficient top water to adjust the reaction to approximately a pH of 7.8-7.9. The water was constantly aerated with compressed air maintaining the 02 of 7-8 p.p.m. The room temperature was usually around 22-22.5° C. The time was noted when fish were placed in this water and again when each fish died. Due to the fact that bass were not available most of the work was done with the golden shiner. Only two experiments were performed with bass. A 19 cm. and a 14 cm. largemouth black bass died in 10,000 p.p.m. of NaCl in 142 and 148 hrs. respectively. In 5,000 p.p.m. NaCl a 20 cm. a 13 cm. and a 12.5 cm. bass survived respectively for 200, 228, and 250 hrs.

Representative results on the effect of varying concentration of NaCl, $CaCl_2$ and $MgCl_2$ on golden shiners are shown in Table I. These results show that $MgCl_2$ kills fish more rapidly than NaCl or $CaCl_2$ at all concentrations used. NaCl kills fish more rapidly at 20,000 and 15,000 p.p.m. than does $CaCl_2$ of the same concentration. At 10,000 p.p.m $CaCl_2$ is more rapidly fatal than NaCl. The difference between $CaCl_2$ and NaCl at 20 and 15 thousand parts per million is, I believe, due to the difference in the rate of absorption of the two salts by the blood. The reason for this belief is that fish that have apparently died in 20,000 p.p.m. NaCl in 30 min. can be revived when placed in fresh water. This not only once but several times. Fish that have died in 20,000 p.p.m. $CaCl_2$ after 2 to 3 hrs. are irreversibly dead. This has been tested out with bream (7.5-12.5 cm); green sunfish (10.0-14.5 cm.) and black bullhead (7.5-8.0 cm). A 14.5 cm. green sunfish retained its equilibrium in 20,000 p.p.m. $CaCl_2$ for seven hours but died the following night in fresh water.

**TABLE I.**

| Salt Used | Concentration P.P.M. | Species | No. of fish | Average Survival time in hrs. | Size of Fish cm. |
|---|---|---|---|---|---|
| NaCl | 20,000 | Golden shiner | 5 | 1.33 hrs. | 9.5-11.5 |
| NaCl | 15,000 | " | 5 | 4.73 hrs. | 10.0-11.0 |
| NaCl | 10,000 | " | 6 | 97.0 hrs. | 9.5-11.0 |
| NaCl | 5,000 | " | 6 | 148.0 hrs. | 8.5-11.0 |
| $CaCl_2$ | 20,000 | " | 5 | 6.4 hrs. | 10.0-10.5 |
| $CaCl_2$ | 15,000 | " | 5 | 17.0 hrs. | 10.0-11.5 |
| $CaCl_2$ | 10,000 | " | 5 | 27.6 hrs. | 9-0-10.0 |
| $CaCl_2$ | 5,000 | " | 4 | 143.5 hrs. | 9.5-11.0 |
| $MgCl_2$ | 20,000 | " | 4 | 0.5 hrs. | 10.0-11.0 |
| $MgCl_2$ | 15,000 | " | 3 | 0.8 hrs. | 9.5-10.5 |
| $MgCl_2$ | 10,000 | " | 3 | 4.6 hrs. | 10.0-11.5 |
| $MgCl_2$ | 5,000 | " | 3 | 96.5 hrs. | 9.5-11.0 |
| $CaCl_2$ | 20,000 | Bream | 10 | 19.5 hrs. | 3.0- 5.0 |
| $CaCl_2$ | 15,000 | " | 11 | 17.7 hrs. | 2.5- 4.0 |
| $CaCl_2$ | 10,000 | " | 11 | 48.8 hrs. | 2.0- 4.0 |

It will be noted that the concentration of the various salts used in

Table I are all rather high. The reason for using such high concentration was to arrive rapidly at some idea of the relative lethal effect of the three chlorides that are most prominent in the salt water from the oil fields. The practical question was: Is the distribution of the various components of this salt water such that if the total salinity, principally NaCl, is reduced to within the limits permitted by law every constituent will be diluted sufficiently to be harmless. This appears to be the case at least so far as the chlorides of Ca and Mg are concerned, both of which appear to be distinctly more poisonous to fish than NaCl. Take the analysis for the Palestine Field for instance. This water will require a 40-fold dilution to reduce the total chloride to conform to the standard set by law. This would reduce the $CaCl_2$ and $MgCl_2$ content to approximately 143 and 42 p.p.m. respectively. In the Luling Field a 17-fold dilution would be required for the total chlorides; this would reduce the $CaCl_2$ and $MgCl_2$ to approximately 181 and 59 p.p.m. respectively. It would appear from the long period of survival of shiners in 5,000 p.p.m. of $CaCl_2$ and also 5,000 p.p.m. of $MgCl_2$ that the values for these two salts arrived at by diluting the water from the Luling Field and the Palestine Field sufficiently to take care of the total salinity would be such as to have no harmful effect on fish.

Another reason for using high concentration of salt is the fact that on at least one occasion the writers found as much as 28,000 p.p.m. of chloride in a stream where fresh water fish were supposed to live.

In these investigations we have used each salt separately. The results may have differed somewhat if various combinations of salt had been used. The antagonistic action of salts undoubtedly accounts for the fact that in diluted sea water, as well as in diluted oilfield water, fish can tolerate higher concentrations of the individual salts than if each salt is used separately.

## Summary

(1) The salt water from the oilfields in Texas constitutes a real menace to the aquatic resources of the State.

(2) This menace can be controlled by impounding these salt waters and by discharging them into the streams at such time when they are able to carry the load.

(3) $MgCl_2$ and $CaCl_2$ have a greater lethal effect upon fish than NaCl.

(4) At high concentrations 20,000 p.p.m. NaCl kills fish more rapidly than $CaCl_2$ of the same concentration. Fish apparently killed in high concentration of NaCl can be revived.

(5) Dilution of the salt water to conform to the limits for total salinity set by law will in all probability render the water harmless for fish life.

## Discussion

Mr. M. P. Adams (Michigan): Our Michigan brine is a good deal stronger than the brine down in Texas. I think Dr. Wiebe mentioned 90,000 parts per million of total solids; ours runs close to 230,000, according to the laboratory reports, and, on chlorides alone, something like 160,000 parts. But in connection with the brine problem in central Michigan oil field areas we can report that substantial improvement has taken place since June first of this year, through the combined efforts of the Department of Conservation and our Stream Control Commission. The fish passed out of the picture some two or three years ago as being unable to resist the concentrations of brine in the upper reaches of the stream. This is tributary to the Saginaw valley. The thing which has apparently brought about sufficient pressure to have the matter cleaned up is the effect on the water supply. The permanent hardness imparted to the water by this brine has upset both the Midland and Saginaw water supplies, a condition which has now been relieved by the corrective measures that have been taken.

# THE VALUE OF CLEAN STREAMS

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The American Fisheries Society for many years has been concerned with the elimination of pollution so I am presenting some information which, while not new, brings together data on some of the values affected by pollution. The value of pure water cannot be reckoned specifically in dollars or cents as can water used for horsepower or irrigation.

The principal value concerned with pollution is public health. The control of water-borne diseases is a primary health measure and polluted waters present a constant menace, even when not directly used as a source of domestic water supply. This most important value is, in general, the basis for pollution control legislation. As is true with many preventative measures, it is most difficult to give a specific evaluation and this is really unnecessary. It is unthinkable that modern civilization will permit the existence of a constant menace to health for which control is easily obtained.

The recreation value of water destroyed by pollution is becoming better appreciated both in its public value and as a direct economic resource, contributing to local business activities. While we cannot set a monetary value on the public benefit derived from the contribution of recreation dependent on pure water, we believe it alone would justify the maintenance of clean waters.

Business and investment values which would be destroyed by pollution are much more definite. On such a lake shore as that at Chicago, the recreation and property values concerned with the lake are largely dependent on pure water and, while substantial, cannot be easily measured. A more direct value can be set in many places. The greater part of recreation uses in our summer playgrounds are dependent on pure water. The annual income from recreation in New England is five hundred million dollars, representing an invested capital of 15 billion dollars. Recreation property there annually pays fifteen millions in taxes. In some of the north central states the recreation business is the second largest industry.

In one section of Wisconsin blessed with abundant clean waters, land assessments for recreation are 63 per cent of the total and on an acre basis exceed farm lands. An area forty miles square represents an investment of $40,000,000 in recreational improvements. While pollution of all these waters is not threatened, the value of the clean water is evident and substantial values are now lost because of present pollution. Industry itself is directly concerned, as many industries require large quantities of water for manufacturing processes which demand a reasonable degree of purity. Such requirements drive industry to locations offering a bountiful supply of pure water.

The Illinois River is a direct example of value destroyed by pollution. This river produced annually as high as 175 pounds of fish per acre, a crop requiring only the protection of the breeding stock and harvesting. Where pollution in the Illinois River is being controlled fisheries production is recovering.

The take of salmon and sea trout alone in the rivers of England and Wales is 1,250,000 pounds. This production is maintained by pollution control in streams flowing through heavily industrialized areas. The Severn, Wye and Tyne produce 140,000 pounds of salmon and migratory trout per stream. The Tyne alone furnished over 11,000 salmon. Pollution is the principal barrier to the rehabilitation of the salmon production of New England rivers which formerly produced many millions of salmon.

The salmon industry of the Pacific Coast is being threatened by pollution. In Oregon this is the third most important industry in the state. In Washington and Oregon the salmon produce an annual income of $15,000,000, representing a capitalization of $500,000,000. The shad industry on the Atlantic Coast has been much reduced by pollution. By improving water conditions, Maryland would be able to increase her present income of $155,000 per year from shad to a much higher figure.

We know that water areas properly managed can produce from 100 pounds per acre to even 800 pounds per acre of fish for controlled ponds. Commercial values do not consider the high recreational values in such water production. Near population centers particularly, these values are very much greater than any commercial use. Pollution destroys large production values from mussel shells and edible shellfish. In many waters pollution may prevent the reproduction and harvesting of water crops developing in large and productive areas not so polluted. This applies particularly to migratory fishes which enter polluted streams from lakes or the ocean.

Since so many of our large rivers are polluted, the proportion of water area affected is great because of the extensive area involved.

An additional value to clean streams lies in the increased real estate values of land adjoining clean water. People find a natural beauty in pure waters and pay a premium to live near them. Any residential development is attracted to clean waters and repelled from those which are polluted. Dr. Carl Hubbs of Michigan cites a specific example at Lansing, Michigan, where fine resident areas have been developed along the Cedar River above the city but are absent along the polluted Grand River below the city. As we are able to enjoy higher living standards this price premium for clean waters is increasing. Certainly millions of dollars in increased real estate values along our rivers would result from pollution elimination.

While public health and the increasing sense of decency demand better water sanitation, I believe we have not paid enough attention to the economics of pure water and can base sound measures of pollution control on a statement of values involved.

It is necessary to maintain both public interest and a legal basis for pollution control. The extension of industry constantly raises new problems or brings new areas under the influence of pollution. The development of paper and pulp mills on the west coast and the inevitable future expansion of industries in the southern states are examples.

Present trends giving support to the clean streams movement are, a better appreciation of the public values at stake, the inadequate supply of game fish and the public demand that all waters be made productive, the development of improved methods of sewage treatment and utilization of industrial wastes, the public expenditure of funds for unemployment, federal assistance in financing sewage works construction, and inclusion of sewage elimination in planning programs developed by state, regional and national planning boards. Municipal and other public agencies, up to February 15, have had a total sum of $134,333,-460 granted in loans and assistance from federal sources to construct sewage works, according to a report of Public Works Administrator Ickes. Such construction has been given a high priority in the assignment of federal funds.

There is still an immense problem ahead since the sewage of only one-seventh of our urban population is now treated. There is the need of greater knowledge regarding the standards necessary. We have used standards indicated by actual killing of fish life and evidence is accumulating that serious results may occur without this direct evidence. Continued research on the effect of pollution on water life is essential. There is a general trend, from a basis of health, effect on the quality of the water, biological values, and physical effects of sludge, to adopt higher standards for sewage elimination.

The basic laws governing pollution control have to do with public health, rights to the use of water, and the English common law of damage. While such laws provide a means for obtaining pollution abatement, it is necessary to establish definite liabilities and to set up an agency charged with the responsibility for enforcement. Such agencies, where most effective, have provided surveys to determine the source and extent of pollution and have authority to abate it. There is a need of broadening the basis of pollution control which, in too many states, is founded on public health without consideration of other substantial values.

In the work which the Izaak Walton League has done through its chapters to improve the legislative set-up for pollution control, there has developed a recognition for the need of uniform and standard provisions. This emphasizes the need of establishing principles of law which will make possible adequate pollution control and bring about uniform practices. A special study of pollution was made by the Izaak Walton League at the request of the President's Conference on Outdoor Recreation. Due to the great variation in local conditions we have not attempted to draft a model law but have endeavored to include essential provisions as indicated in individual cases. Constitutional limitations

and court decisions compel different states to formulate laws on different plans. The first of the few really effective pollution control laws was sponsored by the Illinois Legislature. Commissioner Quinn of Alabama proposes a discussion looking toward the drafting of a model pollution control law, and I am glad to present it here. While the great diversity of pollution problems make drafting of a definite model law very difficult, the setting up of essential principles and uniform practices is most desirable.

One very common complaint from industry and a factor often influencing enforcement concerns variations in requirements. An industry on one side of a state line subject to greater restrictions than the same industries in adjoining states is operating at a disadvantage in competition. This situation has a strong tendency to break down enforcement as well as delay adoption of essential requirements.

Where uniform laws bear equally on all there is encouragement for industry to organize research in waste utilization and disposal to the benefit of the industries as well as the public.

Essential principles for pollution control which have the approval of influential agencies are in an excellent position for acceptance.

The great extent to which waters are interstate and the interstate nature of pollution under such conditions makes it particularly desirable to set up some federal agency to control such waters. The necessity for this is shown by the efforts of several groups of states to coordinate the action to abate interstate pollution. For example Connecticut, New York and New Jersey have attempted a tri-state agreement to control pollution of New York Harbor. Another outstanding state cooperative effort is that of Pennsylvania and New Jersey to control Delaware River pollution. However, state action has proved difficult and cumbersome.

The War Department has jurisdiction over navigable waters and can enforce laws against the discharge of wastes which will obstruct navigation. But these many years the War Department has allowed the discharge of municipal sewage, which is now definitely acknowledged to result in sludge deposits obstructing navigation. While improvement of state action is desirable and cooperation by various states is helpful, there is a sound basis for establishment of an agency which will deal with entire watersheds, as is so effectively done in England by means of pollution control boards. Without going into a detailed discussion of the form this proposal should take, I want to emphasize the importance of the problem and the inadequacy of state jurisdictions alone to meet it. A general federal board with local boards covering separate watersheds may provide the necessary coordination for effective controls. In general on interstate waters, pollution control seems as specifically a matter of federal concern as navigation or water power.

There is a clear need for developing a policy towards sewage control which will dovetail the requirements for pure water by public health, recreation, fisheries and economic interests and develop laws and juris-

diction which will bring about uniform and adequate control of a problem which in many phases is interstate.

With the development of recreation, fisheries and public works and the advancement of planning by state, regional, and national boards, an excellent opportunity is offered to greatly strengthen the clean streams movement.

In considering the possibilities for improving the legal and administrative control over pollution, it must be recognized that state jurisdiction is primarily in health departments rather than in fish and game administration and that the need is evident for greater participation by the federal government.

An agreement is most desirable as to the legal principles essential to a satisfactory pollution law, practices and standards to be made uniform, and types of effective organization for control. These should be determined by agreement between sanitary and water works engineers, commercial and public agencies concerned with fisheries or other biological products of water areas, industrial agencies concerned, state and federal representatives, and conservation groups. Due to the wide scope of problems involved, this might well be designated, "A National Policy on Pollution Control." This would broaden the latitude of the discussion and give full advantage of the possibilities of a meeting of representatives of the various groups just listed.

The Izaak Walton League is now working on a proposal to strengthen federal action since we believe this course offers the best solution to the difficult problem of pollution control on navigable streams. We expect soon to have something definite to report on our proposals to the administration.

Pollution is being considered by the Committee of the American Fisheries Society working on the American Fisheries Policy. A pollution program is also included in the National Fish Policy being formulated by the National Planning Council of Commercial and Game Fish Commissioners.

The greatest apparent need now is to coordinate agencies concerned or already working with this problem rather than to increase the groups operating independently. The Izaak Walton League is glad to take any action which will strengthen the clean streams movement.

## Discussion

Mr. M. P. Adams (Michigan): In connection with Mr. Locke's paper, while I am thoroughly in sympathy with the suggestions he makes, in fact with the paper in its entirety, I can see a number of very difficult obstacles to surmount. I have just completed for our Michigan planning commission, working in conjunction with the National Resources Board, a compilation of the diversity of control over water rights in the state of Michigan alone. One cannot take up the matter of pollution without going immediately into the broader problem of water conservation and the public and water rights which go with it. The matter of water rights and their control in various phases in Michigan is cov-

ered first by the International Joint Commission, affecting boundary waters and our relations with Canada in respect thereto; the Federal Power Commission in connection with certain developments in interstate waters; and then the constitution of the state has given in the first instance to the various boards of local or county supervisors the right to grant permits for the damming and bridging of streams, out of which starvation of certain streams has taken place with all its attendant difficulties. Then, of course, the Conservation Department has separate jurisdiction with respect to streams, and the various health agencies of the state, including the Health Department, cover the matter of nuisance and public health control.

Our Michigan Stream Control Commission is an independent, interdepartmental body within the state, composed of the Director of Conservation, the Commissioner of Health, the Attorney General, the State Highway Commissioner, and the Commissioner of Agriculture. Since 1930 all problems dealing with pollution have passed through that Commission. While I acknowledge that much of the work that has been done has been earmarked as of health significance, I see no reason why, when the thing is analyzed, this problem cannot be approached from the standpoint of protecting the inherent value—both the present and the potential value—of our water resources as such. After all, the only authority which the Health Department has is that vested in the state through its inherent police power, and that police power is there for the protection of the public—peace, health, safety, welfare and morality. If the facts in these cases show an infringement upon the public welfare through the misuse of water, the results should be the same as they are when they act to protect public health. But of course the problem which immediately arises there, and which is going to stand in the way of any completely uniform standard of treatment for all wastes, is this very inherent police power, which in the final analysis must rest on the tests of reasonableness. This matter of water resources is not alone for fish; it is not alone for water supply; it is not alone for recreational values—all of the factors of use must be taken into consideration, including the welfare of our people, which grows out of reasonable and proper use of our water resources, and which in many cases now, of course, is based upon unreasonable use. Industry has gone too far, the public has gone too far, and many of these problems have not been solved.

In Michigan we have at the present time, after a very slow start, some seventeen municipalities all undertaking work under public works loans and grants, involving an estimated total of about $4,000,000, which means a greater rate of progress in cleaning up municipal stream pollution than we have ever had in the state before. On my way here on Monday of this week I attended a conference in Detroit which apparently is seeking to pave the way to a general cleanup of the entire Detroit river problems.

# THE FATE OF OUR FORAGE FISH

Henry C. Markus
*U. S. Bureau of Fisheries*

The presence of shorter working hours has thrown a tremendous burden on our supply of game fish. The condition of our waters has been studied extensively from the propagation, reforestation, pollution and stream improvement phases, but the promiscuous taking of minnows from our waters has been overlooked. It was mentioned by Hubbs and Embody at our 1933 meeting and noted in the Transactions of the American Fisheries Society (Vol. 63, pp. 53-63). It is not the number of minnows that are actually sold to the fishermen that produces this heavy drain on our supply of forage fish, but it is the number of fish that are destroyed in seining for them, the transportation from streams to tanks and the inadequate equipment for holding and caring for them. In order to emphasize these facts the writer wishes to state the results of such careless use of forage fish in the locality of Chandlerville, Illinois.

In 1929, while the writer was employed by the Illinois Natural History Survey, a survey was made of the Sangamon River. In the vicinity of Chandlerville there was an abundance of minnows and small game fish in the streams that emptied into the Sangamon River. In Jobes Creek, minnows and game fish were so plentiful that one haul through a pool with a fifteen-foot seine would fill a ten quart pail with fish. This stream was teeming with *Hybognathus nuchalis*. The following observations were made when a bait seller was getting his supply of bait from this stream. Twenty-five per cent of the catch taken from the stream was left on the bank and water's edge. These consisted chiefly of small fish that went through the meshes of the seine and were trampled into the mud and algae while the desirable minnows were being sorted out. Thirty per cent of the minnows that were put into the cans died while being transported from the stream to a holding tank. Of the minnows put into the holding tank 88.57 per cent died or were discarded and only 11.45 per cent were eventually sold. The percentages with the exception of the first were by actual count. In other words, out of every 1,000 minnows that were taken from the stream 250 died on the bank, 225 died in transportation, 465 died in the holding tank, and 60 minnows were sold. Only six per cent of the original catch was sold to the fishermen. This case no doubt was due to the fact that the minnows were plentiful in the nearby streams.

The results of such careless use of minnows in that locality was impressed upon the writer three years later when he was stationed at Fairport, Iowa, by the United States Bureau of Fisheries to conduct life history studies on forage fish. In the spring of 1932 a visit was

made to Jobes Creek to get *Hybognathus nuchalis*. After spending the greater part of the day seining the stream only one specimen was obtained. Not only were the *Hybognathus nuchalis* practically extinct in this stream, but the same was true of all other fishes including the game fish that three years before had been abundant.

The year after the State survey was made a concrete highway had been completed through this locality thus making the numerous lakes and larger streams in the Sangamon and Illinois River low lands near Chandlerville more accessible. These waters provided good bass fishing and, consequently, the bait dealers had increased. However, they seemed to be taking better care of their minnows since they were difficult to obtain. We talked with one of the bait dealers and showed him the only specimen that we had caught and inquired as to where such minnows could be found. His reply was, "Those are round shiners and we have been getting one dollar per dozen for them, but we can't get them any more." Upon further inquiry it was found that they had to go fifteen miles for their minnows.

Such a change as had come over this locality in three years in depleting the forage fish and small game fish from the smaller streams is certain to decrease the game fish population from the larger waters that are fed by these streams.

In a number of instances the writer has come in contact with live bait dealers, who have the opinion that all small fish are minnows and upon further inquiry as to what they call the small carp, bass, or whatever they may have, they refer to them as carp or bass minnows. The use of these small game or commercial fish as bait by fishermen often introduces species of fish in a body of water where they are undesirable. This may happen by the small fish getting off of the hook or by dumping the bait after the days fishing.

To eliminate the above undesirable conditions live bait dealers should be encouraged to rear their own minnows. Golden shiners (*Notemigonus crysoleucas*), Blunt-nose minnows (*Hyborhynchus notatus*), Black-head minnows (*Pimephales promelas*) and Horned dace (*Semotilus atromaculatus*) may be propagated in ponds and all make good live bait. All the species above mentioned with the exception of the Horned dace have been propagated in ponds by the United States Bureau of Fisheries for many years. No definite sized body of water is required for their propagation. A pond from one-fourth to an acre in area and with a depth of twelve inches on the shallow side to a depth of four feet in the deepest part is desirable. Golden shiners require vegetation in the water for spawning purposes. Any of the forms such as Potamogeton, Myriophyllum, Elodea, or filamentous algae are suitable. Golden shiners have been grown to a length of four inches in a single season at Fairport, Iowa.

Blunt-nose and black-head minnows require pieces of tile, rocks, timber or any similar object with a flat bottom placed in the water horizontally or at an angle to the surface for spawning beds. These objects

must have their flat surfaces far enough from the bottom of the pond to allow plenty of space for spawning activities. Lord (1927: 94-95) states, "The production of black-head minnows per acre on this basis stands at 201,971 or approximately 119 pounds per acre." Markus (1934) produced a yield of 4,414 offspring from a single pair of Black-heads.

In some fishing areas the creek chub, which in most cases is referred to as the horned dace, has become famous as a bait minnow. This minnow no doubt has gained his prominence by its activity and durability on the hook. It too may be propagated in ponds. Its spawning, however, produces another problem for their natural spawning beds are in streams near riffles. This difficulty may be overcome by stripping the milt and eggs from the adults before they begin spawning naturally. The ripe adults give off their milt and eggs very easily; the eggs being handled in the same manner as trout eggs. The fertilized eggs may be put on hatching trays made of cheesecloth tacked on wooden frames or placed in pans in aquaria, the water being changed twice a day. If placed in troughs with running water a very weak stream is all that is necessary.

Horned dace are one of the first minnows to spawn in the spring. They were stripped in Champaign County, Illinois, on April 19, 1930. In Monroe County, New York, they were stripped May 1, 1933, and April 25, 1934. The incubation period in water of room temperature is five days. Eggs taken May 2 at 5:00 P. M. and placed in water at room temperature began hatching the morning of May 6 and completed hatching May 7.

Many of the young hatched from these eggs and reared in a pond attained a length of three and one-half inches by the latter part of September. Leonard (1927: 39) found year-old individuals 3.7 inches long, and also states, "From the graph it is seen that the most rapid growth is made the first year and that the rate decreases considerably thereafter." His measurements as well as those referred to in this paper are from the tip of the snout to the base of the tail.

The writer found that the four species of minnows above mentioned thrive on vegetation and the smaller organisms among the vegetation. Any of the four species not used during the days fishing by the sportsmen may be liberated in any water and should they chance to multiply they would materially aid the stream as far as food is concerned for the game fish, with the exception of the horned dace. If the horned dace is not present in the water being fished, I would hesitate liberating it for it is one of our most voracious minnows.

In conclusion the bait dealer should be encouraged to propagate his own minnows. This would leave the entire supply of forage fish in the streams as food for the game fish thereby increasing the growth and number of these fish. This should result in better fishing which, in turn, will enable the bait dealer to sell more live minnows.

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## Discussion

Mr. Wickliff (Ohio): The last point made by Mr. Markus is a very good one, as to the propagation of minnows in ponds. But I think some of the troubles mentioned by Mr. Markus would be taken care of through the medium of a state law. As I recall it, he stated that twenty-five per cent of the minnows taken were found dead upon the bank. If the state law prohibited this and was enforced, it would cut down the mortality from that cause. Furthermore, I see no reason why minnow dealers could not be licensed, the license specifying how the minnows shall be taken, transported and sold. While that would not correct all the evils, it seems to me it would be of some assistance. In Ohio we try to regulate the way in which our bait dealers handle, transport and sell the minnows.

# SUGGESTED BLACK BASS LEGISLATION, 1935

Talbott Denmead
*U. S. Bureau of Fisheries*

## Preface

In order to adequately protect our valuable largemouth and smallmouth black bass, it is essential that there be: (a) a closed season covering the spawning period; (b) a size limit that will permit the fish to spawn at least once before capture; (c) a reasonable daily limit; (d) a no sale law. At least three months closed season is essential to cover the major part of the spawning period; it is believed a size limit of 10 inches will meet the second requirement; the daily limit should be set at a reasonable figure, one that will discourage fish hogs and prevent waste; the no sale law to be effective should prohibit sale at all times and regardless of where taken—except fish for propagation and restocking.

The following is a tabulation of what new laws are needed to give black bass sufficient legal protection in the states where legislatures meet in regular session in 1935, and their passage will permit these states to obtain the maximum benefit under the Federal Law regulating interstate transportation of black bass:

### Legal Requirements, 1935

FOR FURTHER PROTECTING LARGEMOUTH AND SMALLMOUTH BLACK BASS

| | |
|---|---|
| Alabama | Statewide closed season covering the spawning period (no closed season at present). |
| Arizona | Statewide closed season covering the spawning period (no closed season at present). |
| Arkansas | Longer closed season (now 2½ months). |
| California | Increase size limit to 10 inches (now 9 inches); fewer local exceptions. |
| Colorado | Size limit of 10 inches (none at present); no sale regardless of where taken; later opening date (now May 25th). |
| Connecticut | No major changes required. |
| Delaware | Later opening date (now May 25th); no sale regardless of where taken. |
| District of Columbia | A daily and size limit (none at present); longer closed season (now 2 months). |
| Florida | No sale law covering all waters of state; statewide closed season covering spawning period. |
| Georgia | Longer statewide closed season (now 1½ months); daily and size limits (none at present); no sale at all times regardless of where taken. |

| | |
|---|---|
| Idaho | Size limit increased to 10 inches (now 6 inches) daily limit reduced from 25 to 10 or 15; closed season extended (now 2 months). |
| Illinois | No major changes required. |
| Indiana | Sale prohibited at all times regardless of where taken; closed season extended (now 1½ months). |
| Iowa | The no sale law applies only to hotels, boarding houses, restaurants, dealers, etc., but should be made to apply to individuals as well. |
| Kansas | Statewide closed season to cover the spawning period (none at present). |
| Louisiana | Legislature does not meet in regular session in 1935. |
| Maine | Limit of 25 a day might be reduced; (now 25 fish or 10 pounds and 1 fish). |
| Maryland | No sale at all times regardless of where taken; a uniform statewide closed season covering all tidal and non-tidal waters; one daily limit covering all tidal and non-tidal waters (now 2 seasons and 2 limits and local exceptions). |
| Massachusetts | No major changes required. |
| Michigan | No major changes required. |
| Minnesota | A size limit of 10 inches (none at present). |
| Mississippi | Legislature does not meet in regular session in 1935. |
| Missouri | Prohibit sale at all times regardless of where taken; extend closed season (now 2 months); increase size limit to 10 inches (now 8 inches). |
| Montana | Increased size limit to 10 inches (now 7 inches); extend closed season (now 2 months and 1 week). |
| Nebraska | Extend closed season (now 1 1-3 months); reduce daily limit (now 15 largemouth and 15 smallmouth). |
| Nevada | A ten-inch size limit (none at present); reduce daily limit (now 25); later opening date (now May 1). |
| New Hampshire | Increase size limit to 10 inches (now 9 inches). |
| New Jersey | Increase size limit to 10 inches (now 9 inches). |
| New Mexico | Prohibit sale at all times regardless of where taken; later opening date (now April 1). |
| New York | Later open season in St. Lawrence River (now June 16th). |
| North Carolina | Longer statewide closed season in tidal waters (now 1 2-3 months—9½ months in mountain region on smallmouths); prohibit sale from *all* waters of state at all times. |
| North Dakota | No major changes required. |
| Ohio | Longer closed season (now 1½ months). |
| Oklahoma | Closed season covering the spawning period (none at present); increase size limit to 10 inches (now 8 inches). |

| | |
|---|---|
| Oregon | Increase size limit to 10 inches (now 6 inches). |
| Pennsylvania | Increase size limit to 10 inches (now 9 inches). |
| Rhode Island | No major changes required. |
| South Carolina | Statewide closed season covering spawning period (none at present); statewide daily and size limits (none at present); prohibit sale at all times regardless of where taken. |
| South Dakota | A size limit of 10 inches (none at present). |
| Tennessee | Extend statewide closed season (now 2 months); daily limit (none at present); increase size limit to 10 inches (now 8 inches); prohibit sale at all times regardless of where taken from all waters. |
| Texas | Extend closed season (now 2 months); provide daily limit. |
| Utah | Prohibit sale at all times regardless of where taken; smaller daily limit (now 30 fish or 10 pounds); increase size limit to 10 inches (now 7 inches). |
| Vermont | No major changes required. |
| Virginia | Legislature not in regular session in 1935. |
| Washington | One statewide closed season (now 2 open seasons, April 10-May 15; July 15-November 1, and many local exceptions); increase size limit to 10 inches (now 9-inch limit). |
| West Virginia | Increase size limit to 10 inches (now 8 inches). |
| Wisconsin | No major changes required. |
| Wyoming | Prohibit sale at all times regardless of where taken; a 10-inch size limit (none at present); reduce daily limit (now 30 or 15 pounds). |

## Licenses

*Part-time, non-resident licenses* are now in effect in 19 states. It would be a big help to some of us if more states would adopt this form of anglers' license covering a short period at a reasonable fee.

Several states still have prohibitive non-resident anglers' licenses, encouraging violations, and not materially increasing revenue; a list of state license fees and states having part-time anglers' licenses will be furnished by the U. S. Bureau of Fisheries upon request.

## Sale of Black Bass

The Bureau will also furnish a tabulation of states showing a setup of the existing laws regulating or prohibiting the sale of black bass. Briefly 33 states and the District of Columbia prohibit their sale at all times regardless of where taken; in addition 9 prohibit sale at all times if taken within the state—42 in all. In the remaining 6 conditions are very unsatisfactory.

## Closed Season

Eight states have no closed season on black bass; list furnished on application.

## Game Fish Law Publications

The Bureau has codified and had printed and published the Game Fish Laws of the various states; the supply of the 1933-34 edition (Fisheries Circular No. 16) is exhausted. It will be revised and republished after the 1935 legislatures have adjourned. The cooperation of the various state officials in obtaining the newly-enacted laws as soon as possible after passage will be very much appreciated.

### Department of Commerce

BUREAU OF FISHERIES

July, 1934

### SALE OF BLACK BASS

Sale PROHIBITED at all times REGARDLESS OF WHERE TAKEN:

Arizona
Arkansas
Baltimore, Md.
California
Connecticut
Dist. of Columbia
Idaho
Illinois[1]
Iowa
Kansas
Kentucky
Louisiana
Maine
Massachusetts
Michigan
Minnesota
Mississippi
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New York
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
Texas
Virginia
Vermont
Washington
West Virginia[1]
Wisconsin

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Sale and shipment permitted if taken from CERTAIN waters:

Florida
North Carolina
Tennessee

Sale PROHIBITED if taken WITHIN State:

Alabama
Colorado
Delaware
Indiana
Missouri
New Mexico
South Dakota
Utah
Wyoming

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Sale and shipment PERMITTED at all times if taken OUTSIDE of State:
South Carolina[2]

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Sale PROHIBITED certain TIMES Regardless of WHERE TAKEN:

Georgia—April 15-May 31, inclusive
Maryland[3]—April 1-July 31, inclusive

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[1]Unlawful to serve or purchase bass obtained from any source.
[2]Bass taken within the State can be sold July 1-March 31.
[3]Baltimore City closed at all times.

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Sec. 3 of The Federal Black Bass Law, approved July 2, 1930, provides, in part, as follows: "Any package or container, containing such black bass transported in interstate commerce, except any shipment covered by Section 9, shall be clearly and conspicuously marked on the outside therewith with the name "Black Bass" an accurate statement of the number of such fish contained therein, and the names and addresses of the shipper and consignee."

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This table has been prepared for the guidance of those interested in the present status of the sale of black bass and the Bureau of Fisheries assumes no responsibility therefor. Consult State Fish and Game authorities for additional information.

BUREAU OF FISHERIES, DEPARTMENT OF COMMERCE
Frank T. Bell, Commissioner

ANGLER LICENSES ISSUED AND REVENUE DERIVED, BY STATES, 1932-33

| State | Year | Resident licenses | | Non-resident licenses | | Alien licenses | | Part-time licenses | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | Revenue | Number | Revenue | Number | Revenue | Number | Revenue | Revenue |
| Alabama | 1932-33 | - | - | 186 | $930.00 | - | - | 63 | $124.00 | $1,054.00 gross |
| Arizona | 1933 | 6,139 | $7,673.75 | 337 | 1,011.00 | - | - | - | - | 58,852.25 gross |
| | | 1/20,067 | 1/50,167.50 | | | | | | | |
| Arkansas | 1931-32 | 10,996 | 11,446.20 | 4,151 | 20,357.90 | - | - | 12,473 | 12,670.10 | 44,474.20 gross |
| California | 1932 | 207,625 | 415,250.00 | 2,031 | 6,093.00 | 3,006 | $15,030.00 | - | - | 436,373.00 gross |
| Colorado | 1932 | 1/68,140 | 1/119,274.75 | 2/5,922 | 2/16,287.75 | (2) | (2) | - | - | 135,562.50 gross |
| Connecticut | 1932 | 22,574 | 67,722.00 | 2/1,758 | 2/ 7,870.95 | (2) | (2) | - | - | 112,071.95 net |
| | | 1/7,240 | 1/36,479.00 | | | | | | | |
| Delaware | 1933 | 1/1,347 | 1/1,347.70 | 550 | 2,474.50 | - | - | - | - | 3,822.20 net |
| Florida | 1932 | 9,392 | 21,056.00 | 5,379 | 20,420.00 | - | - | - | - | 41,476.00 net |
| Georgia 3/ | 1933 | - | - | - | - | - | - | - | - | - |
| Idaho | 1933 | 62,051 | 117,896.90 | 1,992 | 9,462.00 | 9 | 85.50 | 2,783 | 5,287.70 | 133,777.10 |
| | | | | 1/22 | 1/1,045.00 | | | | | |
| Illinois | 1932 | 354,927 | 141,970.80 | 2/3,410 | 2/9,377.50 | (2) | (2) | - | - | 151,348.30 net |
| Indiana | 1931-32 | 1/271,752 | 1/244,324.20 | 6,900 | 13,826.00 | - | - | - | - | 258,150.20 net |
| Iowa | 1932-33 | 1/216,328 | 1/210,482.55 | 1,140 | 3,371.75 | - | - | 124 | 124.00 | 213,978.30 net |
| Kansas | 1932 | 74,718 | 74,718.00 | 1,599 | 1,968.00 | 696 | 1,988.00 | 485 | 485.00 | 228,487.00 |
| | | 4/86,341 | 4/86,341.00 | | | | | | | |
| | | 5/20,989 | 5/62,967.00 | | | | | | | |
| Kentucky | 1932 | 51,632 | 43,887.00 | 2,122 | 4,244.00 | - | - | - | - | 48,131.00 gross |
| Louisiana | 1932 | 10,048 | 10,048.00 | 125 | 625.00 | - | - | 1,091 | 1,091.00 | 11,764.00 gross |
| Maine | 1933 | 148,955 | 74,477.00 | 7,099 | 63,790.00 | - | - | 21,275 | 60,031.70 | 220,763.70 net |
| | | 1/22,465 | 1/22,465.00 | | | | | | | |
| Maryland | 1933 | 12,757 | 12,207.86 | 827 | 2,536.20 | - | - | 52 | 104.00 | 14,848.06 net |
| Massachusetts | 1933 | 45,662 | 74,311.75 | 666 | 3,235.25 | 1/14 | 1/210.00 | - | - | 168,066.90 net |
| | | 1/35,742 | 1/90,309.90 | | | | | | | |
| Michigan | 1933 | 270,419 | 135,209.00 | 30,127 | 60,254.00 | - | - | 26,090 | 26,090.00 | 226,335.00 gross |
| | | | | 6/9,365 | 6/4,682.00 | | | | | |
| Minnesota | 1932 | 323,210 | 189,759.15 | 30,608 | 82,641.00 | - | - | - | - | 272,400.15 net |
| Mississippi | 1933 | - | - | 189 | 945.00 | - | - | - | - | 945.00 net |
| Missouri | 1932 | 68,959 | 68,959.00 | 971 | 2,913.00 | - | - | 10,158 | 10,158.00 | 322,912.00 gross |
| | | 1/170,313 | 1/240,862.00 | | | | | | | |
| Montana | 1932 | 1/60,374 | 1/120,748.00 | 2,636 | 9,226.00 | 134 | 1,340.00 | - | - | 131,314.00 gross |
| Nebraska 7/ | 1933 | 1/147,000 | 1/147,000.00 | 350 | 3,500.00 | 10 | 60.00 | - | - | 150,560.00 gross |
| Nevada | 1932 | 5,966 | 8,949.00 | 272 | 816.00 | 17 | 127.50 | - | - | 9,892.50 net |
| New Hampshire | 1932 | 1/51,387 | 1/95,066.35 | 1/1,830 | 1/27,470.85 | (2) | (2) | - | - | 164,755.90 gross |
| | | | | 2/17,993 | 2/42,218.70 | | | | | |
| New Jersey | 1932 | 1/118,698 | 1/320,484.60 | 2/1,994 | 2/8,973.00 | (2) | (2) | - | - | 329,457.60 net |
| New Mexico | 1932-33 | 9,919 | 19,838.00 | 3,801 | 11,403.00 | - | - | - | - | 42,327.50 gross |
| | | 1/2,175 | 1/10,875.00 | 1/ 6 | 1/211.50 | | | | | |
| New York | 1932-33 | 1/435,737 | 1/859,963.10 | 5,301 | 26,185.50 | 640 | 3,520.00 | - | - | 889,668.60 net |
| North Carolina | 1933 | 1/3,034 | 1/4,399.10 | 124 | 620.00 | - | - | 9/207 | 9/124.20 | 17,366.10 net |
| | | 4/2,512 } 5/4,698 } | 10,887.30 | | | | | 8/2,671 | 8/1,335.50 | |
| North Dakota | 1933 | 16,152 | 8,076.00 | 14 | 42.00 | - | - | - | - | 8,118.00 gross |
| Ohio | 1932 | 84,695 | 83,977.00 | 2/718 | 2/2,154.00 | (2) | (2) | - | - | 86,131.00 net |
| Oklahoma | 1932 | 52,047 | 52,047.00 | 337 | 1,510.50 | - | - | 1,850 | 1,850.00 | 55,407.50 gross |
| Oregon | 1932 | 1/13,376 | 1/66,630.00 | 4,281 | 12,843.00 | - | - | - | - | 193,629.00 |
| | | 4/3,580 | 4/5,370.00 | | | | | | | |
| | | 5/36,262 | 5/108,786.00 | | | | | | | |
| Pennsylvania | 1932 | 242,963 | 364,295.00 | 3,357 | 16,525.00 | - | - | - | - | 380,820.00 net |
| Rhode Island | 1932 | 10,414 | 11,455.40 | 104 | 356.70 | 10/164 | 10/410.00 | - | - | 12,227.10 net |
| | | | | | | 11/1 | 11/5.00 | | | |
| South Carolina | 1932-33 | - | - | 108 | 1,080.00 | - | - | - | - | 1,080.00 net |
| South Dakota | 1932-33 | 27,728 | 27,728.00 | 1,353 | 4,059.00 | - | - | - | - | 31,787.00 net |
| Tennessee | 1932-33 | 1/47,934 | 1/81,489.98 | 2/650 | 2/1,381.25 | (2) | (2) | - | - | 82,871.23 net |
| Texas | 1932-33 | 26,738 | 26,738.00 | 85 | 403.75 | - | - | 863 | 863.00 | 28,004.75 net |
| Utah | 1932 | 11,960 | 22,724.00 | 443 | 1,284.70 | 45 | 337.50 | - | - | 74,602.10 net |
| | | 1/22,985 | 1/49,998.50 | 1/ 36 | 1/257.40 | | | | | |
| Vermont | 1932 | 32,697 | 42,627.45 | 2/4,765 | 2/18,902.25 | (2) | (2) | - | - | 88,237.65 net |
| | | 1/19,559 | 1/26,707.95 | | | | | | | |
| Virginia | 1932 | 1/141,156 | 1/181,530.00 | 1/1,949 | 1/22,770.00 | - | - | - | - | 204,300.00 gross |
| Washington | 1932 | 1/166,386 | 1/274,830.00 | 6/996 | 6/2,988.00 | 153 | 1,625.00 | - | - | 307,388.00 gross |
| | | 12/5,577 | 12/27,885.00 | | | | | | | |
| West Virginia | 1933 | 1/14,000 | 1/42,000.00 | - | - | 1,000 | 5,000.00 | 400 | 400.00 | 172,400.00 |
| | | 12/125,000 | 12/125,000.00 | | | | | | | |
| Wisconsin | 1932 | (3) | (3) | 2/43,646 | 2/117,945.30 | (2) | (2) | - | - | 117,945.30 net |
| Wyoming | 1932 | 21,779 | 32,668.50 | 3,740 | 14,960.00 | 10/100 | 10/750.00 | - | - | 89,696.00 gross |
| | | 1/7,685 | 1/38,425.00 | 1/ 48 | 1/2,980.00 | 11/ 1 | 11/ 12.50 | | | |
| Total | | 13/4,553,441 | 13/5,920,952.24 | 14/218,103 | 14/693,248.70 | 5,990 | 30,491.00 | 80,524 | 120,678.20 | 6,775,370.14 |

1. Combination fishing and hunting licenses.
2. Aliens licenses included with non-resident licenses.
3. No recent data received.
4. County combination fishing and hunting licenses.
5. State combination fishing and hunting licenses.
6. Licenses issued to wives of non-resident licensed anglers.
7. Estimated by State authorities.
8. Daily non-resident permits.
9. Daily resident permits.
10. Resident alien licenses.
11. Non-resident alien licenses.
12. Resident and non-resident State licenses.
13. Of this total 2,208,103 licenses with a revenue of $2,174,922.16 were resident fishing licenses and 2,345,338 licenses with a revenue of $3,756,030.08 were resident combination fishing and hunting licenses.
14. Of this total 212,248 licenses with a revenue of $632,520.95 were non-resident fishing licenses and 5,855 licenses with a revenue of $60,727.75 were non-resident combination fishing and hunting licenses.

Note.--These figures have been compiled from statistics obtained from State fish and game agencies and other sources; thus, the U. S. Bureau of Fisheries can not be responsible for their accuracy.

Bureau of Fisheries
May 10, 1934

## List of States Which Have a Part-Time Non-Resident Angler's License, July 1, 1934

| *State* | *Period* | *Cost* |
| --- | --- | --- |
| Alabama | 7 days | $2.00 |
| Arkansas | 15 days | 1.10 |
| Iowa | 6 days | 1.00 |
| Kansas | 15 days | 1.00 |
| Kentucky | 7 days | 1.00 |
| Maine | 30 days | 3.15 |
| Maine | 3 days | 1.65 |
| Maryland (Deep Creek Lake only) | 3 days | 2.25 |
| Massachusetts | 3 days | 1.50 |
| Michigan | 10 days | 1.00 |
| Mississippi | 10 days | 1.50 |
| Missouri | 15 days | 1.00 |
| New Hampshire | 3 days | 1.50 |
| North Carolina | 1 day | .60 |
| Oklahoma | 10 days | 1.25 |
| Texas | 5 days | 1.10 |
| Vermont (Lake Champlain only) | 5 days | 1.50 |
| Virginia | 1 day | 2.00 |
| West Virginia | 1 day | 1.00 |
| Wyoming | 5 days | 1.50 |

## Discussion

Mr. Harrison (Florida): I am sorry to say that Florida is one of the few states that has not yet secured legislation to stop the sale of black bass. In Lake Okeechobee and part of the St. Johns River and part of the Suwanee River, commercial fishermen are permitted to take fish except during the closed season, but it is found that they take them from any other waters and then bootleg them, claiming they caught them in the waters in which such fishing is permitted. But I am glad to say we have assurance that at the next session of the legislature convening in April a law will be passed prohibiting the shipment and sale of black bass, and we want your support in securing this legislation. I believe Florida has the greatest possibilities for black bass of any state in the union. We have 25,000 lakes, thousands of miles of streams, and the climate and natural conditions favorable to propagation of black bass. If we can secure legislation to stop the shipment and sale of black bass and carry out a program of taking the predatory fish out of our waters, which is something we are working on now, Florida will have black bass for all of you, and we hope you will come to Florida to catch black bass.

Mr. Wickliff: I know that the title of Mr. Denmead's paper is Black Bass. I do not care to start another discussion here on the so-called Kentucky black bass such as we had at Hot Springs, but I would suggest that this species be included with the black bass.

# IMPROVED TECHNICAL METHODS FOR DETERMINING THE ANNUAL GROWTH OF SALMON PARR BY SCALE MEASUREMENTS*

DAVID L. BELDING

*Boston University School of Medicine, Massachusetts*

The following methods of determining the annual growth by scale measurements have proved of considerable value in the comparative study of the growth of salmon parr in Canadian rivers. Since similar methods may be employed for other species of fishes, a description of the technic may be of interest. The first is a modification of the scale proportion method, a standard procedure employed by fish investigators. The second is a scale length ratio method devised for the purposes of this investigation. Our results are expressed as the average of the two methods.

*Scale:* The scale of the parr consists of a background of a homogeneous matrix of an irregular elliptical shape crossed by a series of concentric elliptical rings or circuli. The anterior portion of the scale, which is embedded in a recess of the skin, shows most distinctly these concentric lines, parallel to the edge of the scale. On the exposed or visible posterior portion of the scale these lines are irregular and indistinct. The size of the scale and the number of rings depend upon the length and age of the parr.

The intervals between the circuli are not equally spaced and show periodic differences in width, giving the appearance of broad and narrow bands. The former are characteristic of the summer growth, the latter of the slower winter growth. This difference enables the investigator to determine the age of the parr by counting the number of narrow bands on a scale. In the parr the winter zone is characterized by several incomplete or crescentic ridges often coalescing at their free edges and forming the so-called shoulders of the scale. This discontinuity of the striae is characteristic of any temporary check in growth, but especially serves to indicate the winter period. The summer circuli, as a rule, are unbroken throughout the circumference of the anterior portion of the scale. The narrower winter circuli maintain a perfect continuity only in the forward part and become broken or incomplete as they reach the shoulder of the scale. The two features of narrow spacing and broken, incomplete, or branching circuli characterize the winter zone.

*Scale vs. fish growth:* In general the scale increases in size proportionally with the increase in the length of the parr. While this may not be correct for short periods, it holds true over any appreciable length of time. In very cold water scale growth is relatively slower

*Work carried out under the auspices of the Biological Board of Canada.

than parr growth, but this condition only occurs for a brief period in the fall and spring. The slow-growing parr show a proportionally greater increase in scale than in length, and conversely the fast-growing parr give a smaller increase in scale than in length. Errors from this source are avoided by dealing with fairly large numbers. Any changes in the proportionate growth of parr and scale due to age do not apply here, as we are dealing with young fishes. The possibility also must be considered that the scale length may be only proportional to the scale covered body region and may not correspond to head and tail growth at different ages. If the two growths are consistently proportional it is possible, by knowing the length of the parr, to calculate its size at yearly intervals, by measuring the distances anteriorly from the center of the scale to the anterior edge of the scale and to the end of each winter band.

*Measuring the scale:* All scales were obtained from the shoulder of the parr just anterior to the beginning of the dorsal fin and halfway between the lateral line and the mid-dorsal line. Since the locality from which the scale is taken determines its size, it is necessary for consistent results to use always the same locality. Our measurements were recorded in divisions of the ocular micrometer, and all calculations made from these arbitrary units, except when it was necessary to obtain the true length for comparative purposes.

Three factors render inaccurate the measurement of the scales in individual parr. First, the origin of the scale or the starting point of the measurement has to be selected by eye, as it is not fixed. However, this error is hardly appreciable. Second, the scales from the same location on the parr vary in size. To minimize this error ten scales selected of average size were measured for each parr. Third, many deformed or replaced scales in which the first year's growth has been obliterated must be discarded.

## Scale Proportion Method of Calculating Length

*Original method:* Originally as devised by Dahl the scale proportion method consisted in making the proportion $(S/L)=(S1/X1)=(S2/X2)$, etc., in which $S$ = the total length of the scale, S1, S2, etc., = the length of the scale at successive years, and $L$ = the length of the parr. By calculating the proportion for X1, X2, etc., the length of the parr at each year could be obtained.

Since the lengths of the parr and of the scale are not proportional, but only the increments of growth, the initial length of the parr when the scale first forms should be deducted. Salmon have commonly been considered to be about 3.0 cm. in length when the scale is first formed, and this figure has been used by investigators in calculating the length of salmon according to the formula: $(S/L\text{-}3.0\text{ cm.})=(S1/X1)=(S2/X1)$, etc., the actual length being determined as $X1 + 3.0$ cm.

*Modified method:* While the second method was satisfactory for the

rough measurements of the adult salmon, it was not sufficiently accurate for the parr. By direct observations and mathematical calculations the length of the parr when the scales were first formed in the locality from which they were taken was found to be 28.5 mm. Since the scale when first secreted is of a definite size, it was also necessary to determine its initial size, namely .0513 mm. Using these two facts, the yearly length of the parr may be calculated according to the following formula: (S—.051 mm.)/(L—28.5 mm.)=(S1—.051 mm.)/(X1)=(S2—.051 mm.)/(X2), etc., the calculated length at the end of the first year being X1+28.5 mm. and that at the end of the second year X2+28.5 mm., etc.

For example, a 3+ year parr measuring 130 millimeters in length has scale measurements as follows: (1) total length 0.581 mm., (2) 3 years 0.451 mm., (3) 2 years 0.291 mm., and (4) 1 year 0.131 mm. The actual gain in the length of the parr during the period of scale formation was 130 mm. — 28.5 mm. = 101.5 mm. The scale size at the start was 0.05 mm. Therefore the gain in scale length corresponding to the 101.5 mm. gain in length was 0.581 — 0.051 = 0.53 mm., and for the various years 0.40, 0.24, and 0.08 respectively. By proportioning the various scale length for these years according to the proportion 0.53 is to 101.5, the following lengths are obtained from the growing period, 76.6 mm., 44.3 mm., and 15.3 mm. The yearly lengths which are obtained by adding 28.5 are 105.1 mm., 72.8 mm., and 43.8 mm., respectively.

## Scale Length Ratio Method

The second method follows the principle described by Huntsman[1] in his study of scale and length growth in fishes. If the length of the scale is plotted against the length of the parr for a large number of specimens of each length, the result is to all practical purposes a straight line since after the initial scale formation at 28.5 mm. the average growth of parr and scale is proportional. Thus the scale length growth ratio of any river may be expressed by a straight line formula, which represents the average length of scale for each millimeter of parr length. Using the various scale measurements and the length of the parr as in the first method, the length of the parr at various years may be determined from this river standard. The average length of the scale on the river standard corresponding to the length of the parr is determined. The various measurements of the scale are changed into standard figures according to the proportion of the actual measurement of the entire scale to the standard scale measurement, which corresponds to the length of the parr. The scale measurements thus transposed into standard measurements are transcribed either by table or mathematical formula into the calculated length of the parr.

[1]Huntsman, A. G., 1917. Trans. Roy. Sec. of Canada, Ser. III, Vol. XII, Sect. IV, pp. 47-52.

For example, a 3+ year parr measuring 130 mm. in length has scale measurements as follows: (1) total length 0.590 mm., (2) 3 year mark 0.462 mm., (3) 2 year mark 0.285 mm., and (4) 1 year mark 0.127 mm. The standard scale length for a parr of this length is 0.580 mm. Transcribing the other measurements into terms of the standard gives 0.450, 0.280, and 0.125, respectively. The lengths of the parr corresponding to these standard lengths of scales as determined by river formula are 105 mm., 73 mm., and 43.9 mm., respectively.

## Accuracy of Calculations

The reliability of any method of length calculations from scale measurements may be determined by comparing the calculated results with actual measurements of parr of known ages. Table 1 gives the results of calculated lengths in 402 parr and actual lengths in 1560 parr of one and two year parr in the Upsalquitch River, New Brunswick. Allowing for variation in the growth for different years, the calculated results give a very high degree of accuracy.

Table 1. Comparison of Calculated and Actual Lengths of Parr

| | Actual Lengths in Millimeters | | | Calculated Lengths in Millimeters |
|---|---|---|---|---|
| Year | 1931 | 1934 | Aver. | 1930 |
| First year | 44.5 | 48.6 | 46.6 | 46.3 |
| Second year | 74.6 | 76.5 | 75.6 | 75.9 |

## Advantages of Calculated Lengths

The possession of an accurate method of determining the length of parr at different ages by scale measurement has several advantages. In the first place it is possible to obtain from a relatively small number of specimens a wider range of data. For example, from 100 parr collected at the age of three years it is not only possible to obtain the length of 100 three-year parr but it is also possible to obtain the length at one and two years, or the equivalent of 100 one year, 100 two year, and 100 three year parr, thus tripling the numerical value of the collection. In the second place, it is possible to obtain a record of growth during previous years in a river. In the third place, most important of all, it is possible to compare the growth of parr, even though they may be collected at different seasons, thus insuring the utilization of miscellaneous collections from different rivers, irrespective of the time of collection.

# THE VALUE OF QUESTIONNAIRES IN COMMERCIAL FISHERIES REGULATIONS AND SURVEYS

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## INTRODUCTION

I have learned early in my work on the Great Lakes that a very important part of any survey or investigation of the commercial fisheries of a region is the careful assimilation and correlation of the views and opinions of the commercial fishermen of that region. Although not trained as a rule to observe with discrimination much else than the depth and places where fish are most abundant and how they may best be taken in large quantities, the experienced fisherman has nevertheless during his many years of operation accumulated, in a somewhat haphazard manner it is true, a certain amount of information that is of considerable value to the scientific investigator and the administrator of fisheries, if it is properly coordinated and organized. I have found that the acquisition of a wide diversity of opinions from many fishermen and from many localities is one of the best means of approach to commercial fisheries problems. The problems, if not solved thereby, are at least exposed from various points of view and, if the survey of opinions is extensive enough, all the arguments are usually brought out.

Any belief that the average commercial fisherman is an ignoramus and that his opinions, therefore, can not have much value is soon dissipated by personal contact with him. One of the members of my staff once said, "If you want to learn something about the methods of law go to the commercial fisherman. If he does not approve a statute and there is a loophole in it, he will find it." To which I added, "And if there is no loophole—he'll make one." I do not wish to reflect on the attitude of the commercial fishermen toward the law but simply wish to illustrate the point that, moved by some incentive, they are just as keen mentally as any other industrial group of men and that their suggestions are worthy of careful consideration.

To secure the opinions of all fishermen on a wide range of subjects by personal interviews is not only an expensive, laborious and time-consuming task but is virtually impossible, for at best only a small percentage of the fishermen can be reached; and their replies in personal interviews are often hastily conceived. Personal interviews are, of course, indispensable and highly desirable in any survey, but a better and a fairer method to obtain a cross-section of the opinions of the fishermen is by means of a questionnaire.

The questionnaire method is of course not new, but to my knowledge, until we used it on Lake Erie in 1928, it had never before been employed on such a comprehensive scale in a scientific investigation

of the commercial fisheries. When the method was first introduced on Lake Erie there was plenty of skepticism concerning its success, practicability and efficacy. It has, however, now been found workable and expedient among the commercial fishermen; it has proved to be an excellent and inexpensive means to secure a bird's-eye view of the conditions in the field; it has been found highly helpful in the consideration of the laws that govern commercial fishing by revealing the sentiment that prevails among the fishermen. I believe that the use of the questionnaire can be extended considerably by both administrators and investigators with highly beneficial results. It is for this reason that I desire to discuss the subject at this meeting.

### Percentage of Returns

I first employed the method in August, 1928, when I submitted to a selected group of commercial fishermen on Lake Erie a questionnaire that comprised some sixty-eight major questions, or, enumerating both the major and minor, a total of some 179 questions covering the following wide range of subjects: extent of fishing experience, location of fishing grounds, nature of catch, type of gear fished, regulations on gear used, closed areas, spawning seasons, spawning grounds, closed seasons, hatcheries, size limits, collection of statistics, uniformity of laws, administration of laws, factors of depletion, and license fees.

I have often asked myself since then, "What would you do if some stranger submitted a five page, single spaced, typewritten questionnaire and requested replies to some 179 questions?" At any rate, of the 103 U. S. fishermen to whom a questionnaire was sent, some 40 or 39 per cent responded. Such a large percentage of returns exceeded all expectations. The experiment showed beyond doubt that a comprehensive questionnaire can be used successfully among the commercial fishermen of the Great Lakes. Not only did the fishermen respond to a complicated set of questions but, on the whole, they were also able to understand the questions and express their views intelligently.

On the strength of the success of the Lake Erie experiment, the Department of Conservation of the State of Michigan in cooperation with the U. S. Bureau of Fisheries submitted in March, 1932, a comprehensive questionnaire to its licensed commercial fishermen on the Great Lakes. This questionnaire, patterned after the one used on Lake Erie, comprised some sixty major questions, or, enumerating all questions that required an answer, a total of 267 covering all the important phases of the state's commercial fisheries. Some 500 questionnaires were returned by the Michigan fishermen or about 43 per cent of the approximately 1,175 sent out.

Similarly in November, 1932, the Department of Conservation of the State of Wisconsin submitted a commercial fishing question-

naire to its licensed fishermen on the Great Lakes and received as good a response as did Michigan. Some 415 questionnaires or 43 per cent of the 972 sent out were returned. Wisconsin's questionnaire, following closely the one drawn up for Michigan, contained 58 major questions or a total of 346 major and minor questions.

It is of interest to note that the percentage of returns for Michigan and Wisconsin, 43 per cent, agreed fairly well with the percentage obtained for Lake Erie, 39 per cent, in spite of the fact that the total number of questions in the state questionnaires was 1.5 and 1.9 times that in the Erie questionnaire. The states' percentages would be increased if all who were not regular commercial fishermen but who fished only with a few gill nets from a rowboat or through the ice during their leisure time were eliminated from the computations. It is quite certain that very few, if any, of these casual fishermen would be interested enough to fill out and return the questionnaire. It must also be explained that very few fishermen answered all the questions in the state questionnaires since replies were requested only when the fishermen had first hand knowledge on the subject. For example, a gill netter who had no experience with pound nets was instructed to ignore all questions that pertained to pound nets; and vice versa. It may be explained further that, whenever possible, the question was put in such a form that a reply could be made in a very few words, often by a check mark.

## Tabular Presentation of Opinions

In order to analyze readily the information secured, the data were compiled by subjects in tabular form for each lake as well as for the entire state, and the number of replies as well as the percentage of this number in the total was recorded for each category. In addition cumulative percentages were also computed where possible so that it could be determined, at a glance, not only how many fishermen or what percentage of them favored a certain regulation but also what percentage favored this regulation or a more strict regulation.

Let me illustrate. Question five in Michigan's questionnaire reads in part "What size mesh in gill nets do you recommend for . . . . whitefish?" The table compiled for this question is so arranged that it shows at a glance for each lake and for the entire state the number of replies received, the number of men favoring each size mesh, the percentage of this number in the total, the number of men who favor a certain mesh or larger meshes, and the percentage of this number in the total. (Table 1.)

Thus the table shows that on every lake the big majority of the fishermen favor a 4½ inch mesh, that out of the total of 360 replies for the entire state 274 or 76.1 per cent favor a 4½ inch mesh, that 355 or 98.6 per cent favor a 4½ inch or larger mesh, that 81 or 22.5 per cent favor a mesh larger than 4½ inches and that five replies or 1.4 per cent favor a mesh smaller than 4½ inches. All other infor-

TABLE 1. ILLUSTRATING THE METHOD OF PRESENTING THE FISHERMEN'S OPINIONS IN TABULAR FORM

| Lake | Mesh | 3½ | 4 | 4¼ | 4½ | 4⅝ | 4¾ | 4⅞ | 5 | 5½ | 6 | 6½ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Michigan | No. | | | 2 | 152 | 13 | 12 | | 5 | | | | 184 |
| | % | | | 1.1 | 82.6 | 7.1 | 6.5 | | 2.7 | | | | |
| | C* No. | | | 184 | 182 | 30 | 17 | | 5 | | | | |
| | C % | | | 100.0 | 98.9 | 16.3 | 9.2 | | 2.7 | | | | |
| Huron | No. | 1 | 1 | | 35 | 7 | 10 | | 2 | 1 | | | 57 |
| | % | 1.8 | 1.8 | | 61.4 | 12.3 | 17.5 | | 3.5 | 1.8 | | | |
| | C No. | 57 | 56 | | 55 | 20 | 13 | | 3 | 1 | | | |
| | C % | 100.0 | 98.3 | | 96.5 | 35.1 | 22.8 | | 5.3 | 1.8 | | | |
| Superior | No. | | | 1 | 87 | 2 | 9 | | 12 | 6 | 1 | 1 | 119 |
| | % | | | 0.8 | 73.1 | 1.7 | 7.6 | | 10.1 | 5.0 | 0.8 | 0.8 | |
| | C No. | | | 119 | 118 | 31 | 29 | | 20 | 8 | 2 | 1 | |
| | C % | | | 100.0 | 99.1 | 26.0 | 24.3 | | 16.7 | 6.6 | 1.6 | 0.8 | |
| | Mesh | 3½ | 4 | 4¼ | 4½ | 4⅝ | 4¾ | 4⅞ | 5 | 5½ | 6 | 6½ | Total |
| Entire State | No. | 1 | 1 | 3 | 274 | 22 | 31 | | 19 | 7 | 1 | 1 | 360 |
| | % | 0.3 | 0.3 | 0.8 | 76.1 | 6.1 | 8.6 | | 5.3 | 1.9 | 0.3 | 0.3 | |
| | C No. | 360 | 359 | 358 | 355 | 81 | 59 | | 28 | 9 | 2 | 1 | |
| | C % | 100.0 | 99.7 | 99.4 | 98.6 | 22.5 | 16.4 | | 7.8 | 2.5 | 0.6 | 0.3 | |

*C = Cumulative.

mation in the questionnaire was similarly arranged to facilitate comparison at a glance.

## Reliability of Opinions

The question may now be asked, "How reliable is the information that is obtained from these questionnaires, especially that dealing with regulatory measures?" In the consideration of this important question Michigan's questionnaire will be used as a basis for discussion and the subjects therein may be divided into three categories: 1. Information of a purely statistical nature. 2. Information of a biological character. 3. Information on regulations.

1. *Statistical Information.* Information of a purely statistical nature, such as, name and address of fisherman, number of years of experience, ports fished, kind of gear used, and the species composition of the catch may safely be accepted as quite accurate.

2. *Biological Information.* Information of a biological character pertains to such questions as: seasonal variation in the catch, spawning seasons of the different species of fish in the different areas of a lake, location of spawning grounds, size at sexual maturity of the different species of fish, the length-weight relationship of various species at their legal size limit, the effectiveness of artificial propagation, depletion of fish, and the factors involved in depletion.

The data on the seasonal variation of a species in the catch, and the location of spawning grounds were found to be quite accurate. With respect to spawning seasons a wide range of opinions occurred. For example, in the case of the lake trout in the Michigan waters of Lake Michigan some eighteen different dates ranging from October first to November fifteenth were given as marking the beginning of the spawning period, while some twenty-two dates ranging from October tenth to December twentieth were given as the end of the spawning season. Similar wide ranges of opinions were found in the case of other species. Part of these discrepancies is no doubt explained by the variation in spawning time in the different localities as well as in different years. However, by determining the mode and the median of each range a fairly accurate idea is obtained of the average spawning period. Thus, in the case of the lake trout the Michigan questionnaires showed that the average spawning season in Lake Michigan as determined from each median is October fifteenth to November fifteenth, and as based on the modal points, October tenth to November twentieth. The extremes of these dates more than cover the spawning period which is believed to extend from about October fifteenth to November twenty-first. Table 2 shows other interesting comparisons. In most cases the extreme dates based on the median and modal points are found to delimit very closely the actual spawning season.

TABLE 2. AVERAGE SPAWNING SEASONS. STATE OF MICHIGAN

| Lake | Source of data | Lake trout | Whitefish | Yellow pike-perch | Perch |
|---|---|---|---|---|---|
| Michigan | Various records | Oct. 15-Nov. 21 | Nov. 1-Dec. 15 | ——— | ——— |
| | Median* | Oct. 15-Nov. 15 | Nov. 10-Dec. 15 | April 1-30 | May 1-June 1 |
| | Mode* | Oct. 10-Nov. 20 | Nov. 1-Dec. 15 | April 1-30 | May 1-June 15 |
| Huron | Various records | Oct. 10-Nov. 15 | Nov. 1-Dec. 1 | April 1-30 | ——— |
| | Median | Oct. 10-Nov. 4 | Nov. 12-Dec. 1 | April 1-20 | April 20-May 31 |
| | Mode | Oct. 10-Nov. 4 | Nov. 20-Dec. 15 | April 1-10 | May 1-June 1 |
| Superior | Various records | Oct. 1-Nov. 6 | Nov. 1-30 | ——— | ——— |
| | Median | Oct. 10-Nov. 1 | Nov. 10-30 | ——— | ——— |
| | Mode | Oct. 10-Nov. 1 | Nov. 1-Dec. 15 | ——— | ——— |

*All median and modal values were based on Michigan's questionnaires (see text).

With respect to the question of young fish virtually all of Michigan's fishermen (98.4 per cent) stated that the size limits should always be high enough to protect immature fish, but the minimum size limits recommended did not always meet that requirement. This is, of course, not startling since a critical study of the size at sexual maturity really demands the services of a trained biologist. The range of recommended size limits was considerable in the more important species, but here again, as in the case of spawning seasons, the median or modal values gave fairly good results. Size limits stated in terms of weight protected larger fish than those given in terms of total length. This is partly due to the fact that the fishermen did not have accurate data on the length-weight relationship of their fish and that this length-weight relationship varies somewhat with localities.

Table 3 compares the size limits recommended by the Michigan fishermen, as determined from median and modal values based on questionnaires, with those recommended by the Bureau at the present time. The two series of size limits expressed in terms of weight agree perfectly while those expressed in lengths show some disagreement, the fishermen recommending the lower size limits, except in the perch.

TABLE 3. MINIMUM SIZE LIMITS. STATE OF MICHIGAN

| Measurement | Source of data | Whitefish | Lake trout | Yellow pike-perch | Perch |
|---|---|---|---|---|---|
| Total length in inches | U. S. B. F. | 18½ | 18½ | 17½ | 9 |
| | Median* | 17 | 16½ | 16 | 9 |
| | Mode* | 18 | 16 | 13 and 16 | 9 |
| Weight in pounds and ounces | U. S. B. F. | 2—0 | 1—8 | 1—8 | 0—5½ |
| | Median* | 2—0 | 1—8 | 1—8 | 0—6 |
| | Mode* | 2—0 | 1—8 | 1—8 | 0—5 |

*All median and modal values were based on Michigan's questionnaires.

Concerning the question of hatcheries, some 70.5 per cent of Michigan's fishermen believe in the effectiveness of artificial propagation although there are no adequate criteria by which to judge the correctness of this belief. To illustrate how thoroughly the combined views of the commercial fishermen can cover a subject I wish to quote the foot-note to our summary table on the question of hatcheries. "Those who believed that hatcheries are beneficial pointed out the recent increases in the abundance of whitefish and trout; some stated that planting had led to the rehabilitation of areas in which certain species were almost extinct; others pointed out the importance of protecting spawn from the tremendous inroads of lawyers, suckers, pilots, etc.; that the 85-90 per cent yield in hatcheries represents far greater efficiency than natural hatching; that by means of hatcheries, areas with few good spawning grounds can still support a good fishery.

"Those who held that hatcheries are of no benefit pointed out that since plantings were begun fishing has not improved; that on the contrary it has in many cases become poorer; that spawn gatherers 'catch tons of fish' where they produce a few quarts of spawn—most of the spawn 'goes in the gut barrel'—much green spawn is collected and the natural spawn damaged by nets; that hatchery reared fish are not viable but die in the unaccustomed conditions of the open lake; that the small fish planted can not find food and fall easy prey to enemies. Many held that there should be a completely closed season to protect natural spawning. One held that the abundance of fish depends on natural conditions and the effect of hatcheries is of little significance.

"There were several opinions to the effect that spawn should be collected only by the state."

If any one here can contribute important new material to these arguments he is welcome to try it.

As in the case of artificial propagation, so also is the question of depletion and the factors involved therein a very complicated one whose solution must await careful scientific inquiry. But, a summary of the views of Michigan's fishermen on this subject is very illuminating in that it lists some thirty-seven causes of decrease in abundance. I doubt whether any one individual could enumerate so many reasons for the disappearance of commercial fish. Causes mentioned ten times or more are, in order of importance: pollution, overfishing, fishing during spawning season, deep trap nets, chub nets, small mesh in gear, migration, destruction of small fish, pound nets, shallow trap-nets, gill nets, and lack of protected closed seasons. Perhaps nowhere is the reliability of the questionnaire brought out better than here, for even in the details of the relative importance of the causes there is little room for dispute. Here again, we have an excellent demonstration of the value of assimilating the various views of the fishermen at the beginning of a fisheries survey.

3. *Information on Regulations.* The third category comprises the remaining subjects of the questionnaire and deals with the fishermen's views on the questions of regulation, such as those concerned with: proper mesh in different types of gear for different species of fish, maximum length of lead in impounding nets, minimum distance between impounding nets set in a string and between strings of these nets, maximum length of these strings, maximum percentage of illegal fish permitted in small-meshed gill nets, restrictions on the use of deep trap nets, hooks, and other types of gear, closed areas, closed seasons, zoning of lakes, method of measuring size limits, uniform laws, control of fisheries, criticisms of laws, administration and enforcement, discretionary power, and assessment of fees.

To illustrate the value of the questionnaire with respect to these controversial subjects that affect the daily operations of the fishermen themselves, the sizes of mesh recommended by the Michigan fishermen are compared in Table 4 with those recommended by the U. S. Bureau of Fisheries and with those now in effect in Michigan. The table shows that there is a remarkably close agreement between the recommendations of the majority of the fishermen and of the Bureau, and that there is a tendency on the part of the fishermen to follow the regulations already in effect. Virtually all of the other recommendations on regulations (Table 5) may be considered good conservation measures. These recommendations likewise reveal a tendency to follow present regulations or otherwise the common practices already in vogue. Because of the latter tendency one is able to secure from the questionnaires much information on the details of the current types of gear and on their use in the field.

**TABLE 4. SIZES OF MESH RECOMMENDED BY MICHIGAN FISHERMEN AND THE U. S. BUREAU OF FISHERIES, AND FOUND IN EXISTING LAWS. STATE OF MICHIGAN.**

| Regulation | Michigan Fishermen | | U.S. Bureau | Present |
|---|---|---|---|---|
| | Median | Mode | of Fisheries | Law |
| Mesh in pot of pound and shallow trap net for whitefish and lake trout | 4″ | 4½″ | 4¾″ | 4½″ |
| Mesh in pot of pound and shallow trap net for yellow pike-perch | 2¾″ | 2¼″ | 3½″ | 3½″ or less |
| Mesh in pot of pound and shallow trap net for lake herring | 2¼″ | 2″ | 2¼″ | 3½″ or less |
| Mesh in pot of deep trap net for whitefish and lake trout | 4½″ | 4½″ | 4¾″ | 4½″ |
| Mesh of gill net for whitefish, lake trout, and yellow pike-perch | 4½″ | 4½″ | 4¾″ | 4½″ |
| Mesh of gill net for chubs | 2¾″ | 2¾″ | 2¾″ | 2½″, 2⅝″-2¾″ |
| Mesh of gill net for lake herring | 2½″ | 2½″ | 2½″ | 2¼″, 2½″, 2⅝″-2¾″ |
| Mesh in wings of seines | 4″ | 4″ | —— | 4″ |
| Mesh in bag or pocket of seines | 2½″ | 3″ | —— | 2¼″ |

To answer our query, then, we may conclude that in Michigan the questionnaire, particularly when based on the opinions of the majority, provides a considerable amount of trustworthy information,

TABLE 5. RECOMMENDATIONS ON REGULATIONS BASED ON THE MAJORITY OPINION OF THE COMMERCIAL FISHERMEN. STATE OF MICHIGAN

| Regulations | Fishermen's recommendation | +approved —disapproved |
|---|---|---|
| Maximum length in rods of the lead in pound and shallow trap nets | 40 | + |
| Maximum length in rods of the lead in deep trap nets | 60 | + |
| Should the distance between lead of one net and the back of the next net be regulated | no | — |
| Minimum distance in feet between lead of one net and the back of the next net recommended by minority for shallow trap nets | 25 | + |
| Minimum distance in feet between lead of one net and the back of the next net recommended by minority for pound and deep trap nets | 50 | + |
| Should the minimum distance between strings of pound or shallow trap nets be regulated | yes | + |
| Minimum distance between strings of pound or shallow trap nets | ½ mile | + |
| Should maximum length of strings of pound and shallow trap nets be regulated | no | — |
| Maximum length of strings of pound and shallow trap nets recommended by minority | 3 nets, 1 mile | + |
| Percentage of fishermen opposed to use of deep trap nets | 63.3 | + |
| Maximum percentage of illegal fish permitted in small-mesh gill nets before removal becomes mandatory | 10 | + |
| Shall the use of hooks be prohibited | no | + |
| Shall trolling for commercial purposes be prohibited | no | + |
| Shall the use of seines be prohibited | no | + |
| Maximum length of seines in rods | 80 | + |
| Do you favor closed seasons during spawning periods | yes | + |
| Do you favor closed seasons during periods other than spawning seasons | no | — |
| Should lakes be zoned for closed seasons | | |
| Lakes Michigan and Huron | yes | + |
| Lakes Superior and Erie | no | + |
| Should size limits be based on weights | yes | — |
| Should all scientific, hatchery, and enforcement work on commercial fisheries be entirely supported by license fees | no | + |
| Should there be uniform laws on gear, size limits and closed seasons | yes | + |
| Do you favor discretionary power | yes | + |

and gives an accurate cross-section of the views of the fishermen. As a rule, information that involves a careful study of measurements must be accepted with some reserve. These conclusions apply also to the Lake Erie questionnaires, and no doubt to those of Wisconsin.

## Practical Application of Questionnaire

The administrator of fisheries may at times make effective use of the questionnaire in his contact with the legislators. The legislator is as a rule highly sensitive to the sentiments of the majority and reacts accordingly. The struggle to restrict the use of deep trap nets in Michigan might not have been so intense had the information been available that sixty-three per cent of the fishermen were absolutely opposed to the use of this net and that another twenty-five per cent wanted them rigidly restricted. Or the recent lowering of Michigan's restriction on the size of mesh in chub nets on Lake Huron might have been prevented had it been kown at the time that eighty-six per cent of the chub-net fishermen on this lake opposed the change and that not one Lake Huron fisherman recommended a mesh as small as that enacted into law. Two recent attempts to lower restrictions were actually forestalled in Michigan when it was shown that the majority of the herring fishermen on Lake Superior opposed a decrease in the size of mesh in herring gill nets, and that fifty-one per cent of the fishermen favored a nine inch size limit for perch rather than the proposed eight and one-half inch. Similar instances also occurred recently in Wisconsin when a majority opinion among the fishermen drove out the deep trap net and defeated attempts by a group of fishermen to prohibit all fishing during closed seasons.

A comprehensive questionnaire may serve, therefore, not only to guide the administrator in his recommendations on the fisheries but also to help him in making effective these recommendations and in preventing the enactment of undesirable legislation. My copies of the summary tables based on Michigan's and Wisconsin's questionnaires have become indispensable in my work on the Great Lakes fisheries. Such summaries would prove to be even more indispensable to the fisheries administrator who is unfamiliar with the nature of the problems that confront the commercial fishing industry and who has no access to expert advice.

In conclusion, I wish to express my indebtedness to the Department of Conservation of the State of Michigan, particularly to my friend, Mr. Fred Westerman, for permission to compile and use the information contained in Michigan's questionnaires. Dr. Ralph Hile and Mr. William Duden of the Bureau's Great Lakes staff compiled the summary tables upon which the conclusions of this paper were based.

## Discussion

Mr. Bode (Iowa): In sending out the questionnaire did you use any special device to enlist the interests of the fishermen so that they might be induced to return it?

Dr. Van Oosten: Yes, each questionnaire was accompanied with a letter—a very short letter, one page—explaining the use to which it was to be put.

Dr. MacKay (Ontario): In the compilation of the various answers to your questionnaire, to what extent were they supervised?

Dr. Van Oosten: You mean, in compiling the information?

Dr. MacKay: Did you send anyone out to the various parts to explain any of these points to the fishermen?

Dr. Van Oosten: No, we simply sent the questionnaire to the licensed fishermen, through the mail, with this letter, and that was all.

Dr. MacKay: I thoroughly support your view, because we sent out questionnaires to the fishermen on the Great Lakes and we got back very satisfactory answers.

Dr. Van Oosten: Did your questionnaire contain as many questions as ours?

Dr. MacKay: No, not nearly as many—not more than six.

Dr. Van Oosten: Of course that would be successful. The surprising thing is we had three hundred and fifty questions.

Dr. MacKay: That is the reason I asked you if you had any supervision.

Mr. Langlois: May I ask Dr. Van Oosten if in calculating these figures he took into consideration simply the expression of opinion of a single fisherman without regard to the extent of his operations?

Dr. Van Oosten: Yes, we simply compiled the answers, giving each fisherman an equal amount of credit.

The President: As I recall them, they agreed remarkably well, did they not, in the different localities where conditions were quite similar? You, of course, studied them much more intensively than we did, even though we had called for the questionnaire.

Dr. Van Oosten: Yes, they agreed—there was a wide range in the answers, and I have touched upon the explanation for that. There is a variation in the spawning season, with localities, with the lakes, and with the years, which would account in part for the diversity of opinion. That is referred to in my paper.

# THE LIFE HISTORY AND ECOLOGICAL RELATIONSHIPS OF THE ALEWIFE (*POMOLOBUS PSEUDOHARENGUS* [WILSON]) IN SENECA LAKE, NEW YORK[1]

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The work covered by this paper was prompted by the need for a new forage fish in many of the lakes of New York. The work of the New York State Biological Survey has pointed to the desirability of finding a plankton-eating forage fish suitable for planting in some of the lakes of the state. What was known about the alewife in the Finger Lakes indicated that this species might serve the purpose. The collection of material was begun during the summer of 1927 and was continued through January, 1934.

The alewife is an anadromous marine fish inhabiting the coastal waters of North America from Nova Scotia to North Carolina.[2] It occurs as a land-locked species in certain lakes of New York, especially Lake Ontario and some of the Finger Lakes. Opinions as to the method of introduction into these lakes have been offered by Seth Green,[3] Tarleton H. Bean,[4] and Hamilton L. Smith.[5] Whatever its method of introduction, the alewife has become an abundant species in the lakes under consideration. In the summer it is wide-ranging in habit, having been taken at all depths down to 160 feet. The winter distribution is unknown.

The Atlantic alewife spawns in the streams and ponds along the coast. In the Finger Lakes it spawns in shallow water in the lake proper, the spawning season extending from late May or early June to the middle of August. There seems to be no preferred type of bottom. The swirling and splashing which accompany spawning are familiar to all who spend much time in the vicinity of the spawning areas.

The alewife eggs can be fertilized and hatched easily by artificial means. Females 145 millimeters long, standard length, contain from 10,000 to 12,000 eggs each. The author was successful in hatching eggs which had been stripped from live fish and fertilized in trays in running tap water whose temperature ranged from 56 to 60° F. and in standing water with a temperature range of 60 to 74° F. The incubation time varied from 81 to 132 hours. The fry are positively phototropic and pelagic. The yolk-sac is absorbed in about three

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[1]An abstract of a thesis presented to the Faculty of the Graduate School of Cornell University to satisfy the requirements for the degree of Doctor of Philosophy.
[2]Nichols and Breder: Zoologica, vol. 9, No. 1, p. 38. Jordan, D. S.: Manual of the Vertebrate Animals. Bean, T. H.: Fishes of New York, 1903, p. 199.
[3]Roosevelt and Green: Fish hatching and fish catching, Rochester, N. Y., 1879. Also Green, Seth: Forest and Stream, 1880, 15, p. 167.
[4]Bean, T. H.: in "The Fishery Industries of the U. S." G. B. Goode, U. S. Fish, Com., 1884, p. 588.
[5]ibid.

days. All attempts to keep the young fish alive after the sac had been absorbed were unsuccessful.

Age determinations of 668 specimens were made by the scale method following Lea's work on the herring.[6] The mean, median and modal length for each year of growth was calculated. They are given in Table 1. The mean length for each age is plotted in Figure 1.

TABLE 1. MODE, MEAN AND MEDIAN OF STANDARD LENGTHS OF ALL FISH USED IN GROWTH STUDIES

| Age Group | Number Males | Number Females | Males Mode | Males Mean | Males Median | Females Mode | Females Mean | Females Median |
|---|---|---|---|---|---|---|---|---|
| 0+* | 108* | | 27 | 24 | 25 | ---- | ---- | ---- |
| 1+* | 113* | | 57 | 55 | 56 | ---- | ---- | ---- |
| 2+ | 65 | 24 | 117 | 114 | 115 | 120 | 121 | 120 |
| 3+ | 147 | 137 | 127 | 121 | 122 | 127 | 125 | 126 |
| 4+ | 27 | 22 | 142 | 139 | 140 | 130 | 134 | 133 |
| 5+ | 11 | 14 | 142 | 140 | 140 | 137 | 139 | 138 |

*The fish in these collections were immature.

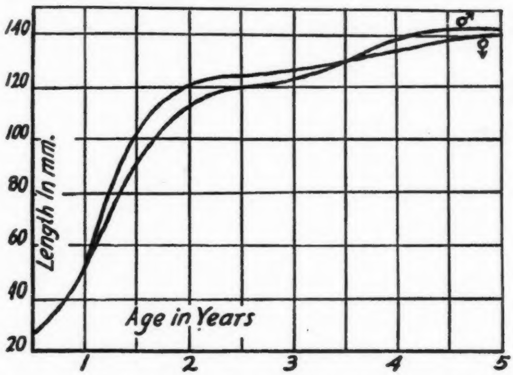


Figure 1.—Rate of growth as shown by mean standard lengths of all fish used in growth studies.

A comparison of the calculated mean length for each age and the measured mean length for each age is as follows:

| | | | | | |
|---|---|---|---|---|---|
| Age of fish in years | 1+ | 2+ | 3+ | 4+ | 5+ |
| Measured lengths, mm. | 55 | 117 | 123 | 136 | 140 |
| Calculated lengths, mm. | 55 | 111 | 126 | 137 | 144 |
| Difference, mm. | 0 | 6 | 3 | 1 | 4 |

The only wide difference occurs in the two-year group. This difference can be explained by an analysis of the data. There is a great

[6]Lea, Einar: Report on the age and growth of herring in Canadian Waters, Canadian Fisheries Expedition 1914-15. Dept. of Naval Service, 1919.

difference between the rate of growth of different individuals which is brought out in Tables 2 and 3.

TABLE 2. COMPARISON BETWEEN THE MAXIMUM AND MINIMUM GROWTH INCREMENTS

| Year increments | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ |
|---|---|---|---|---|---|
| Minimum, mm. | 33 | 22 | 2 | 5 | 3 |
| Maximum, mm. | 95 | 74 | 40 | 34 | 11 |

TABLE 3. EXTREME VARIATIONS IN LENGTH OF FISH OF THE SAME AGE AT THE TIME OF THEIR COLLECTION

| Age in years | 1-3 Mo. | 1+ | 2+ | 3+ | 4+ | 5+ |
|---|---|---|---|---|---|---|
| Minimum length, mm. | 21 | 30 | 100 | 104 | 119 | 129 |
| Maximum length, mm. | 31 | 76 | 130 | 148 | 158 | 150 |

The long spawning season and the differences in food and habitat probably account for much of this variation in rate of growth.

The length-weight relationship was worked out by the method of moments using the formula "$W = aL^n$." The number of specimens used was 616. The results are given in Table 4.

TABLE 4. VALUES FOR "a" AND "n" FOR THE ALEWIFE OF SENECA LAKE

| Age and sex | Values for "n" | Values for "a" |
|---|---|---|
| 225 immature | 2.78 | 0.017 |
| 211 adult males | 2.41 | 0.064 |
| 180 adult females | 2.28 | 0.093 |
| Average of all specimens | 2.51 | 0.055 |

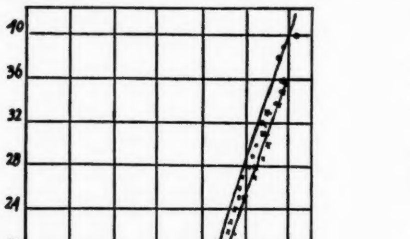


Figure 2.—The length-weight relation. The dashed line represents a break in the data.[7]

It will be noted that the increase in weight of the young is small in proportion to the increase in length. As the fish reach maturity the increase in weight is greater in proportion to the increase in length. This trend reaches its maximum in the adult females. The length-weight relationship is represented graphically in Figure 2.

The food of the alewife was determined by the examination of 653 stomachs. Eighty per cent of these contained food. The stomach of each specimen was opened and the kinds of food recorded. All of the food from the stomachs in one collection was lumped and

[7]There were no specimens for the age group which comes between the one year olds of June and the two year olds of the following June.

then sorted according to types. Each type of food was centrifuged and the volume measured. The results are given in Figures 3 and 4.

All of the fish eggs taken were those of the alewife. The four specimens which had eaten fish had taken their own young. Microcrustacea made up 46% of the volume of all food taken. They composed 59% of the volume of the stomach contents of the collections of fish which had not taken eggs. The number of specimens which had taken each kind of food is shown in Figure 5, the percentages being figured on the basis of the stomachs which contained food.

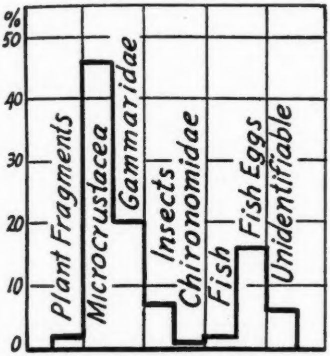

Figure 3.—The food of all specimens by per cents.

Microcrustacea made up not only the greatest volume of food consumed, but more than half of the fish examined had taken this type of food. Insects were taken

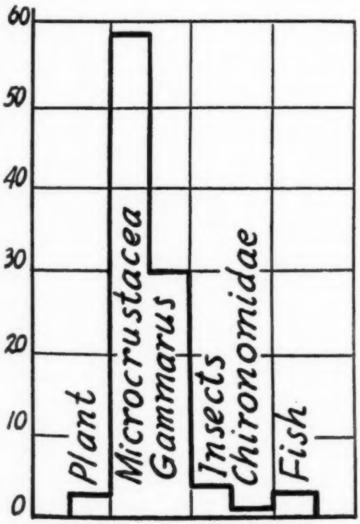

Figure 4.—The food of collections which did not contain fish eggs, by per cents.

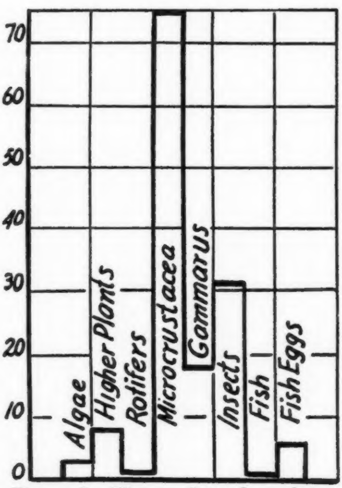

Figure 5.—The number of specimens which contained each kind of food, by per cents.

by the next largest number of fish and *Gammarus* by the third largest number.

A study was made of the kinds of food taken at different times of the year. The results are recorded in Figures 6, 7 and 8.

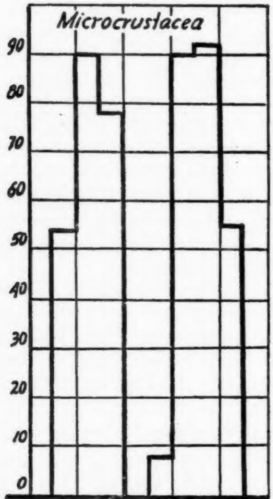


Figure 6.—The per cent of microcrustacea in the stomach contents by months.

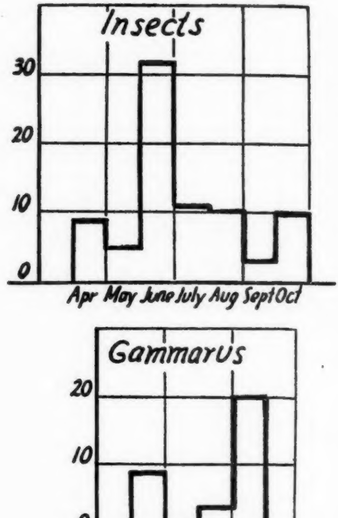


Figure 7, 8.—The per cent of Gammarus and insects in the stomach contents by months.

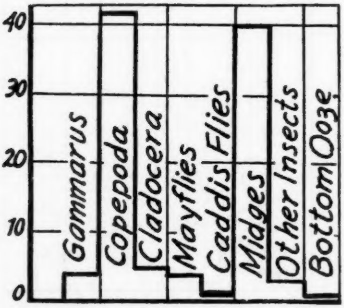


Figure 9.—The food of 336 alewives from the Oswego Survey Report.

Permission was secured to include the data on the food of alewives gathered during the Oswego Survey of the New York State Conservation Department. The fish came from Seneca, Cayuga and Keuka Lakes and the identifications were made by Dr. Charles K. Sibley.[8] This material is summarized in Figure 9.

These fish had taken the same kinds of food in about the same

[8]N. Y. State Cons. Dept., Sup. to 17th Annual Rpt., Albany: 1928, p. 48,

proportions as the ones collected and studied by the author.

A study of the data leads to several conclusions. First, that the alewife feeds principally on animal plankton, but if other suitable food is available in abundance it is taken, as in the case of eggs, insects and *Gammarus*. Second, that the alewife feeds only on material which is floating or swimming freely in the water. Terrestrial insects form a considerable part of the bill of fare at irregular intervals. Winged ants, black flies and crane flies were found in the stomachs of several individuals. The author has seen alewives jumping for adult caddis flies.

One question always asked about the alewife is "Why does it die in such large numbers at periodic intervals?" Many theories have been advanced to explain this irregular mortality. The author expects to do further work toward solving this problem.

It may be recalled that this study was undertaken because of the hope that the alewife might prove to be a suitable forage fish. This species has been known as an excellent food for lake trout since the time of Seth Green. He says,[9] "I have discovered that the alewife, commonly called 'saw-bellies,' breed in our inland lakes. . . . This discovery I consider very valuable, as there is no better food for all kinds of fish, and especially the salmon trout. . . . They are more valuable food fish than the fresh water herring or young whitefish, because they are spring-spawning fish, and breed much faster. . . . The alewife hatches at least one thousand young for every one of the fresh water herring or whitefish, and their value as a food fish is inestimable. . . .

"To show that all kinds of fish feed on them, I have caught, with them for bait, salmon trout, black bass, rock bass, perch, pickerel and bullheads."

Finger Lakes fishermen have reported finding the alewife in the stomachs of a variety of fish including the following: pike-perch, northern pike, bass, pickerel, cisco, perch, lake trout and rainbow trout. The Finger Lakes Survey Report[10] records them from the stomachs of lake trout, pickerel, eel and perch. Ninety-nine per cent of the 108 stomachs of lake trout examined contained alewives. The author has taken the alewife from the stomachs of ciscoes, smallmouth black bass and perch from Seneca Lake. It is evident that the alewife might serve as food for a number of carnivorous species. In places where a forage fish is lacking and where the ecological factors are suitable it should be introduced. The author believes that the alewife is a much more desirable fish to introduce into lakes to serve

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[9]Green, Seth.—The alewife in fresh water, Forest and Stream, 1880, 15, p. 167.

[10]New York State Conservation Dept., Sup. to 17th Annual Rp't., Albany, 1928.

as a forage fish than the Atlantic smelt. His reasons may be summarized as follows.

The alewife is well adapted to life in deep, cold lakes and is wide-ranging in such lakes during the summer months at least. It multiplies rapidly. More than half of its food consists of microcrustacea. It takes fish so rarely that it may be considered a non-fish-eating species. It probably does not take fish eggs except incidentally and only when they are floating. It is utilized as food by several species of fish wherever it is established.

At the time when the original paper was written it was the author's belief that the alewife was adapted only to fresh-water lakes in which there is a thermocline. During the past summer it was his good fortune to discover that the alewife thrives in Ballston Lake and Round Lake in New York State. Round Lake is only 29 feet deep and is warm throughout. Besides that the oxygen conditions on the bottom are very poor. Ballston Lake has deep water, 116 feet, and a thermocline. But there is practically no oxygen in the deeper portions and the deepest portions contain bog water. It is evident from these findings and those of Dr. Sherman C. Bishop who has been working on the Mohawk River and the Barge Canal that the alewife is a very tolerant species.

The question arises as to the best method to employ in making an introduction of alewives into a body of water which does not contain them. The adults can be seined during the spawning season. But they are very difficult to transport alive. The fry can be seined in large numbers during late summer and the fall. They can be transported without undue loss. The eggs can be secured by stripping, fertilized artificially and hatched easily. The selection of the best method will be left to the fish culturists.

## Acknowledgments

The author is deeply indebted to the following for assistance in some part of the work:—Dr. George C. Embody, Dr. James G. Needham, Dr. Walter H. Durfee, Dr. Elon Howard Eaton, Messrs. Ellsworth H. Wheeler, Henry P. Peglow and George A. Harer. Dr. Carl L. Hubbs suggested the problem.

## Discussion

Dr. Van Oosten (Michigan): You refer to the discrepancies between calculated and actual length measurements. Did you encounter in these calculated results Lee's phenomenon? What I mean is: Did you find in comparing your calculated results for the same year of life for fish of different age groups a progressive decrease occurring in these calculated results with an increase in the age of the fish from which the scales were taken?

Mr. Odell: Yes. The additional length decreased from year to year, but the

difference between the calculated and measured length in the first year was six, in the second year three, in the fourth year one. It jumped up the next year, but I do not think fish in the sixth summer can be taken to mean very much.

DR. VAN OOSTEN: That phenomena is usually found in calculated results, but in certain species it has not been found, and I was interested to know if it had been found in your case. I would like to ask another question. I was surprised to learn that the cisco fed on the alewife. Did you find that they did so very extensively?

MR. ODELL: I was very much surprised too, but I had many reports from the fishermen at Geneva to the effect that they had had considerable success in catching them with small alewives, and we have very often found them in their stomachs. I tried to secure stomachs but was able to obtain only a few from the fishermen; in those which I did get, there were alewives in three out of four.

DR. VAN OOSTEN: What size were the ciscoes?

MR. ODELL: I think they were about nine to eleven inches. They were large ciscoes.

DR. VAN OOSTEN: It is very interesting to learn that.

MR. THADDEUS SURBER: Have you any lake trout in this deeper lake you refer to?

MR. ODELL: No. I do not know whether any attempt was made to introduce them, but there was a question as to whether they should be introduced, and our findings were conclusively opposed to it.

MR. THADDEUS SURBER: Many of our northern Minnesota lakes, particularly those right along the border—purely lake trout lakes—are more or less aquatic deserts, and we are up against it for forage fish. I have been wondering whether or not the alewife would prove to be a good forage fish to introduce in those lakes. There is a certain supply of microcrustacea in all these lakes, but we are limited in the production of lake trout because of the absence from many of these lakes of forage minnows.

MR. ODELL: Many people have attributed the excellent lake trout fishing in Keuka lake especially, and Seneca lake too, to the presence of the alewife. Of course, I am not sure that is the answer.

MR. THADDEUS SURBER: It might be the answer.

MR. ODELL: They are very abundant in both those lakes. I am not in any way a fish culturist—that is, I know nothing about the hatchery side of it; but I went out last summer and caught some fish in a gill net, stripped them into photographic developing trays, let them stand for a few minutes, poured off the water, carried them up to the laboratory and turned on the tap and hatched them, so they must be fairly hardy. With some of them I turned off the running water after a few hours and left them on a lab table, and they hatched too.

MR. THADDEUS SURBER: It is barely possible they could be transported some distance, but I doubt it; they might not be able to withstand a much lower temperature.

MR. MARKUS: I would like to ask whether Mr. Odell has observed the method by which the lake trout feed on these alewives.

MR. ODELL: No, I have not.

MR. MARKUS: The common belief held by many sportsmen around that section of the country is that the big lake trout lie near the bottom and wait for the time when the alewife is just about ready to die, and get him in that way. Have you any evidence as to whether or not that is so?

MR. ODELL: No.

# REARING LARGEMOUTH BLACK BASS AT LONOKE

JOE HOGAN
*State Fish Hatchery, Lonoke, Arkansas*

This paper treats in part with the details of operating the ponds devoted to the rearing of largemouth black bass at the Arkansas hatchery during 1933.

During the spawning season a greater number of brood bass per pond was used than in previous years. The effects from this change were not only in the increased number of fry produced per pond but also resulted in a slower, more uniform growth of the fry in the spawning ponds before their transfer to the rearing ponds. This uniformity in size made it much easier to find and catch large numbers of fry about the same size for stocking the rearing ponds. Previously quite a bit of trouble was experienced in catching large numbers of the same size for stocking purposes. The output of fry per broodfish, however, may not have been as great as when fewer brood bass were used.

The brood fish were wintered in ponds well stocked with forage minnows, and at the approach of the spawning season were culled, sexed and transferred to the spawning ponds. The importance of having a broodstock in excellent condition cannot be overstressed, for adult fish in poor flesh at spawning time have little value. Forage minnows were then fed sparingly until the ponds were drawn in June. A majority of the spawning ponds were stocked with a ratio of two males to three females and three spawning ponds were stocked with a ratio of one male to two females, all with satisfactory results. This made it possible to dispose of about three hundred male fish, which is quite a saving in feed. For the past two seasons the largest broodbass have been placed in a spawning pond by themselves for comparison with the average sized fish and have failed to produce as well. We prefer fish weighing about two pounds for brood stock.

Reference is made to the desirability of controlling temperatures in the spawning ponds where it is possible to do so. We refer to the 1934 season. Pond No. 1 was filled with water from the well at a temperature of 65° and stocked with 90 adult bass on March 15. This is rather late for our locality; however, at this time the other spawning ponds were partly frozen over. The warm water was not chilled before moderate weather arrived and practically the entire lot of brood stock spawned at one time. A high per cent of eggs hatched and a few weeks later over 100,000 advanced fry were removed from the pond in one day. Just across an eight foot levee in pond No. 2, which had been filled with water well in advance of the spawning season, the eggs were chilled by the low temperatures and practically all of the nests except a few in the deepest water were lost.

During this season only three rearing ponds were used with forage

minnows for the young bass. The results of two of the ponds would indicate that where forage fish are used under the right conditions there is a tendency to reduce cannibalism by producing plenty of feed and a more even growth in the fingerling bass. The results of the other pond only prove that where the necessary requisites for a balanced condition are lacking, the use of forage minnows does not correct the wrong and the production of the pond naturally falls below the average.

Our opinion of conditions under which forage minnows should be used is as follows:

1. The water level in the rearing pond should be brought to the proper height well in advance of the bass spawning season to let the aquatic vegetation and insect life get an early start. This insures food for the adult minnows, protection for their eggs during the incubation period, and protection for the small bass early in the season when it is of great importance.

2. A good growth of vegetation is desirable not only as early as possible in the season but throughout the season. The growth of vegetation will be checked by the excessive use of fertilizer and this should be avoided. The proper amount of fertilizer to use will be an amount sufficient to produce an abundance of insect life, yet will allow the vegetation to make a normal growth and will also avoid deoxygenation of the water to an extent that would be harmful to the fish.

3. The forage fish should be placed in the rearing ponds about the time the first bass eggs are spawned. This should keep the minnows from spawning too early and would prevent the young minnows from outgrowing the fingerling bass. It is important that a good supply of minnow fry be on hand in the rearing ponds when the young bass are introduced. This will insure an even start among the young bass and will go a long way toward the elimination of cannibalism during the entire season.

With the practice of using the medium or small medium sized minnows as a broodstock for forage purposes in the rearing ponds one season and feeding them to the adult bass in the fall and winter, the minnows are utilized as food and the stock is kept moving. By fall when the bass rearing ponds are drawn, the minnows have increased in size and weight and are very desirable as forage of the adult bass. Thus it will be seen that forage minnows, while populating a bass rearing pond with minnow fry during their second summer, are also fitting themselves as feed in the winter ponds of the adult bass.

The golden shiner has been propagated with satisfactory results by the aid of fertilizers during the 1934 season. Although the fertilizer has been used to stimulate the vegetation and insect life in the ponds, the cottonseed meal is taken readily by both the adult and young minnows, the fish breaking the water and feeding at the surface over

the entire pond when the fertilizer is applied. The ponds have been stocked with about 100 adult minnows per acre and have been fertilized with cottonseed meal and superphosphate on a weekly schedule from May 1 to September 1.

We believe there is a decided advantage in drawing the bass rearing ponds as soon after September 1 as possible. The heat makes it impossible to drain the larger ponds at Lonoke at that time but all the smaller ponds are drawn where it is possible to remove the fish early in the morning, before the heat of the day. The survival in ponds drawn early was higher than in ponds drawn late in the season and it is thought that the large fingerlings are responsible for the lower survival. Wild ducks are sometimes credited with some of the damage, for late in the season as many as five thousand ducks are on the hatchery ponds at one time.

The fish in our rearing ponds are subject to attacks from many native predators and a constant warfare must be waged against the grebe, several species of the heron family, terns, kingfishers and snakes. A conservative estimate placed on the number of water-moccasins killed on the hatchery would be about seven hundred a year. One employee during April and May by actual count killed over three hundred snakes.

We are quite firmly convinced that the most logical method of rearing bass under the present conditions is to create a natural food supply in the rearing ponds by the use of fertilizers. No artificial food has been fed throughout the summer and the fish were totally dependent upon the supply made available in the ponds. The climatic conditions along with the nature of the ponds lead us to believe that it is necessary to apply small amounts of fertilizer to the pond surface each week during the summer season. The first two applications of fertilizer were at the rate of fifty pounds per acre and twice as large as was used during the remainder of the season, our intention being to build up the action of the fertilizer to its desired effects early in the season and then to maintain this productivity during the remainder of the season by the regular addition of small amounts.

The rearing ponds were fertilized on a regular weekly schedule with two parts cottonseed meal to one part 18% superphosphate from May 1 to August 14, except for a few times when the oxygen content would not permit. The cottonseed meal was purchased at $.70 per hundredweight and superphosphate at $.76 per hundredweight. The extent of the carry-over from fertilizers used the year before was noted in ponds having been fertilized with about three hundred pounds per acre for the season. The effect first appeared about April 1; by June 1 it was at its height, and by early July had completely disappeared. Some types of vegetation can stand more fertilizer than others and when the extent of fertilization becomes so great as to kill the more tender forms, it adds to the decomposition along with the fertilizer and a serious condition is apt to result.

In heavily stocked ponds where no fertilizer is used, the growth rate of fingerling bass is retarded soon after a length of two inches is attained. In fertilized ponds after the fish have made a growth of three inches and the fertilizing is stopped, very little growth is made regardless of the time when the ponds are drawn. Our objective, to insure food in the ponds, is to continue to fertilize until the fish make a three inch growth.

The production of the various ponds devoted to rearing bass fingerlings was as follows.

Eighteen ponds that had been used as spawning ponds with a combined area of 14.9 acres were restocked during June with 142,000 No. 1 fingerlings. The ponds were fertilized for the remainder of the summer with 4,450 pounds of cottonseed meal and superphosphate. No forage minnows were used. The ponds were drawn in October and 101,226 fish averaging 3.34 inches long were recovered. The number of select fingerling fish in this lot of ponds was exceedingly low and reflects the benefit of sorting young bass at one inch in length. The average survival in these ponds was about 71% and the production was at the rate of 6,793 fish per acre.

Nine ponds with a combined area of 35.85 acres were stocked during April and early May with an estimated 705,000 fry. These ponds were fertilized during the summer with 12,050 pounds of cottonseed meal and superphosphate. No forage minnows were used. The ponds were drawn during the months of September, October and November, recovering 327,605 fish with an average length just over three inches. The average survival in this lot of ponds was about 46% and the production at the rate of 9,138 fish per acre.

Three ponds with a combined area of 11.45 acres were stocked during the latter days of April with an estimated 235,000 fry. These ponds were also stocked with 5,400 adult golden shiners for forage broodstock and were fertilized during the summer with 4,350 pounds of cottonseed meal and superphosphate. The ponds were drawn in September, October and November, yielding 83,302 fish with an average length of 3.9 inches. The average survival in these ponds was 35% and the production at the rate of 7,275 fish per acre.

Two ponds with a combined area of 5.85 acres were operated throughout the summer as combination spawning and rearing ponds. These ponds were stocked with thirty-four adult female bass and twenty-three adult male bass and 3,000 select adult golden shiners on March 1. The ponds were fertilized throughout the summer with 2,050 pounds of cottonseed meal and superphosphate and a limited amount of cow manure. No mortality was experienced in the broodstock of one pond during the summer, while in the smaller pond of .85 acres the seven adult fish placed in it were lost from unfavorable conditions on June 27. These ponds were drawn in September and October, yielding 43,660 fish with an average length of 3.37 inches,

making an average production of 7,463 fish per acre. Judging from the number and size of the fish produced in these two ponds we have estimated the initial stock of fry to have been about 110,000 with a survival of about 40%.

Summing up the fingerling bass production at Lonoke for the season, we operated thirty-two rearing ponds with a combined area of 68.05 acres. During the summer 22,900 pounds of cottonseed meal and superphosphate were used to fertilize the ponds at a cost of $164.88. In the fall a total of 555,793 fish averaging 3.4 inches long were recovered, making a survival on the entire area of 46.79% and an average production per acre of 8,167 fish.

# THE NEW BASS HATCHERY AT SOUTH OTSELIC, NEW YORK, AND ITS FIRST YEAR'S OPERATIONS

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The purpose of this paper is to present some of the data obtained during the 1933 season at the new bass hatchery at South Otselic, New York, which was the first year of operation for this hatchery.

For years the New York State Conservation Department has been operating a bass hatchery near Ogdensburg on the St. Lawrence River, but fish have not been reared on artificial food during the summer. Bass fry are hatched at the Oneida Hatchery at Constantia on Oneida Lake but are planted as fry in most cases.

I do not want to enter upon a detailed description of the South Otselic Hatchery at this time. Suffice it to say that the hatchery consists of ten acres of ponds divided up as follows: one, one and one-half acre pond for holding brood stock; one, one and one-half acre spawning pond; eight, one-half acre rearing ponds; two, one-quarter acre rearing ponds; and a series of thirty-six small Daphnia ponds which drain into the rearing ponds.

The water supply comes from the Otselic River, a warm, clear, rapid flowing stream. A dam across the stream diverts the water into an open ditch, where it is taken by a pipe line to the hatchery site.

The data for the 1933 spawning season may be summarized as follows: All breeders were wild fish netted out of their native lakes the first and second weeks of May. The spawning season started on May twelfth and ended May twenty-first, with a single stray fish spawning on the twenty-fifth. The peak of spawning occurred on May sixteenth.* Water temperatures increased from 57.5° F. at the beginning of the egg-laying to 66° F. at the end. Though my data are not, perhaps, extensive enough to prove this point, yet it seems that the earlier nests were the most successful. Thus, fry were obtained from every nest made during the first four days of spawning, but only one-third of the nests made during the last four days of spawning. The time from the laying of the eggs to the first appearance of black fry averaged nine days. No conclusions concerning temperature units can be drawn from the small amount of data. Eggs were deposited on 72 nests, of which 44 were successful. The average number of fry obtained from twenty-five of the successful nests was 3,557, making a total of 88,928.

At the present time anyone engaged in raising bass is of necessity

*In Ohio in 1933, the peak of the spawning season had been reached during the first week in May. Langlois, T. H. 1933. Trans. Am. Fish. Soc. Vol. 63, p. 400, while the peak of our spawning season had not been reached until the third week. Our season ends earlier, so that we have a much shorter time in which to produce large fish.

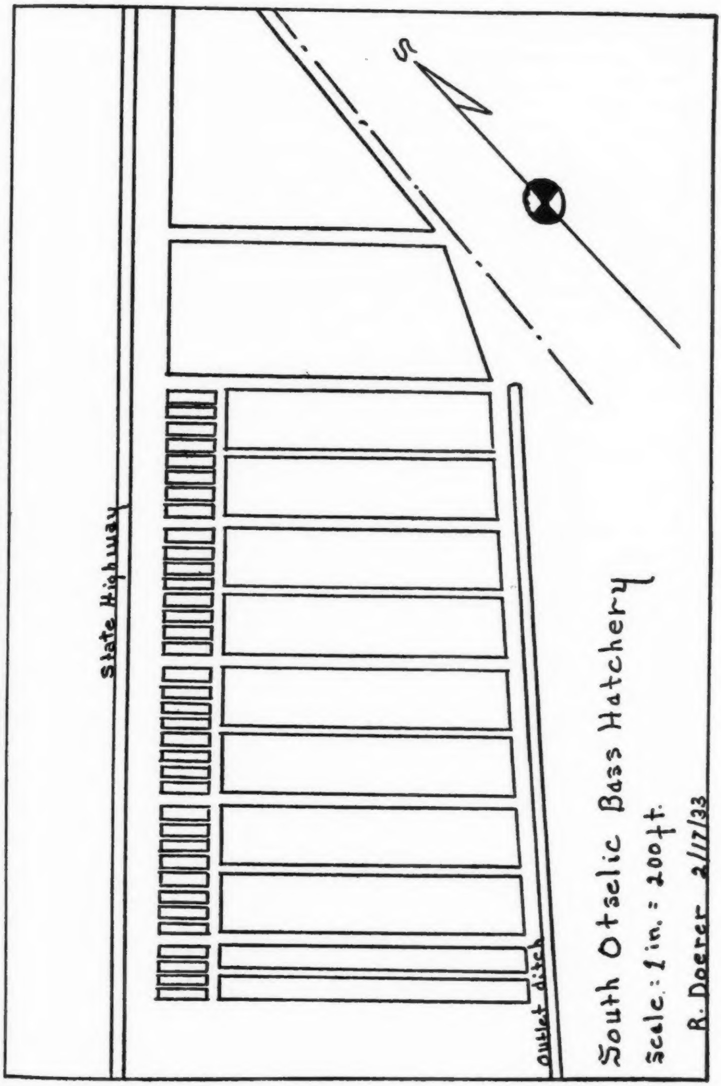


FIGURE 1—CONSTRUCTION OF HATCHERY

somewhat of a pioneer; therefore, I think a brief account of our methods at South Otselic is justified.

In the early part of the spring the rearing ponds are sterilized with a solution of chlorinated lime to eliminate the Dragon fly nymphs and other organisms which are harmful to bass fry. This procedure is accomplished by spraying the ponds with the solution while they are drained but still wet. As soon as the pond is sprayed it is allowed to fill with water and stand until it is time to fertilize it.

In the past few years bass culture has been based on the production of Daphnia as a source of food until the young fish attain a size large enough to take artificial food. The Daphnia may be produced in the bass rearing ponds or in special Daphnia ponds. At South Otselic we have done both. Previous to the introduction of fry into the rearing ponds, these ponds have been supplied with a good Daphnia culture.

Piled or fresh cow manure is used to fertilize the rearing ponds to make them ready for the introduction of Daphnia. The one-half acre ponds require about thirty-five cubic feet of fresh manure to produce a good tea color. If piled manure is used, we find that double the amount is necessary to give the same effect. It is necessary to add more fertilizer from time to time to maintain the tea color. During the period of three to four weeks in which the ponds are allowed to produce Daphnia before the bass fry are introduced, we find that we have to add about fifteen cubic feet of fresh manure every four or five days. Four good wash tubs of Daphnia are sufficient to innoculate the pond at this time. During this period and up to the time artificial feeding is started, the water is stagnant in the ponds, the level being maintained by the control boxes.

The rearing ponds, after they have been made ready for the bass fry, are stocked at rates of either fifty thousand or one hundred thousand per acre, the fry for this purpose being taken directly from the nests. One pond in each of the first two sets was stocked at the rate of one hundred thousand per acre while the companion pond in one case was used for the production of golden shiners as a forage minnow, and in the other case goldfish. One pond in each of the remaining sets of half-acre ponds was stocked at the rate of fifty thousand per acre and the companion ponds were stocked with goldfish. At the time these ponds were stocked, it was decided to allow the bass to feed on the forage minnows when they were about one and one-half inches long. However, the minnows outgrew the bass and it was necessary to feed all ponds artificially. Each of the one-fourth acre ponds was stocked at the rate of fifty thousand per acre and fed artificially when the Daphnia supply would no longer support them.

Pond number one was stocked on the twenty-eighth of May, while pond number three was stocked on the thirty-first of the month. Pond number five was stocked on the second of June, and ponds numbers seven, nine, and ten were stocked on the third.

With eight Daphnia ponds for each set of rearing ponds, it is

possible to drain a culture every fourth day for each pond of young bass. This allows sixteen days for the production of a culture. As each rearing pond has a water capacity of approximately sixty thousand cubic feet and each Daphnia pond a capacity of one thousand cubic feet, it follows that for each fifteen cubic feet of bass rearing space, one cubic foot of Daphnia propagating space is allowed.

During the 1933 season three different fertilizers were used in the Daphnia ponds, namely, cow manure, dry sheep manure with acid phosphate, and soybean meal. It was found that only half as much fresh cow manure was required to fertilize a pond as when piled manure that had lost much of its strength was used. The soybean meal cultures were the easiest to produce, since less labor was involved. Good cultures were obtained with the dry sheep manure but the cost of production was higher. Table 1 gives a summary of the amounts of these fertilizers used to fertilize a pond with a capacity of one thousand cubic feet, together with the length of time required for the culture and the cost of the fertilizer used.

**TABLE 1. DAPHNIA CULTURES**

| Fertilizer used | Total amount fertilizer used | Period in days | Cost |
|---|---|---|---|
| Piled cow manure | 9.25 cu. ft. | 16.4 | $0.43 |
| | 9.5 cu. ft. | 26.6 | .44 |
| | 17.5 cu. ft. | 17.6 | .81 |
| | 13.7 cu. ft. | 29.8 | .63 |
| Dried sheep manure | 143 qts. | 25.5 | 1.90 |
| with acid phosphate | 86.9 qts. | 30.7 | 1.16 |
| 1:8 | | | |
| Soybean meal | 21 qts. | 20 | .54 |
| | 21.5 qts. | 29.4 | .56 |
| | 23 qts. | 28 | .59 |

The time required for a peak culture of Daphnia is governed by many factors. One of the most important of these is the number of Daphnia used to innoculate the newly fertilized pond.* We have allowed some of our cultures to run as long as thirty days (Table 1), but this does not mean that such a period was required to produce a good culture. Sometimes we had more Daphnia than we needed, so held a culture until required. An excellent culture should have about one pound of Daphnia to each one cubic foot or approximately ten pounds for each one of our ponds.

From my experience at South Otselic it seems to be advisable to have frequent Daphnia cultures throughout the summer to drain into the rearing ponds. Sometimes the culture in a rearing pond starts to decline before the fish are large enough to feed and it is necessary to supply them with more Daphnia. At the time the fish are learning to take artificial food it seems advisable to drain Daphnia into the

*At the experimental hatchery at Cornell University, Professor Embody used twenty-five cubic centimeters of Daphnia by volume to innoculate one hundred cubic feet of water and I have been innoculating at the same rate in the Daphnia ponds at South Otselic. With an innoculation of this character it takes from sixteen to twenty-one days to produce an excellent culture.

rearing pond to keep the fish in good condition. Later on, there are many small fish in the ponds that need Daphnia and it appears desirable to feed Daphnia to these smaller fish in order that the pond may have a maximum production.

Many enemies of the Daphnia occur in the propagating ponds. The worst of these are the backswimmers and the beetle larvae. Both of these can be eliminated by spraying the surface of the pond with cod-liver oil or salmon oil. At this hatchery cod-liver oil mixed with gasoline in a ratio of one to three is used. On a still, warm day the backswimmers and beetle larvae can be killed off in fifteen to twenty minutes by spraying the surface of the pond with this mixture. Other organisms such as *Hydra* have not occurred in our cultures, but when organisms of this nature do occur, it is advisable to drain the pond and sterilize with chlorinated lime.

Artificial feeding of the young bass is started about the time they are from one to one and one-half inches long. Up to this time the fry have been feeding on the Daphnia produced in the rearing ponds and on those introduced from the Daphnia ponds. At this time the food is ground very fine so that it will sink slowly, giving the fish more time to take it before it settles on the bottom. Sometimes live Daphnia are stirred in with the ground food in order to coax the young fish to accept the new diet.

A variety of artificial foods was used at South Otselic during the 1933 season. Among these were shrimp, canned marine herring, frozen herring, frozen goldfish, carp, and beef heart. Dried skim milk was used in some of the rations, which seemed to make the food more buoyant. One ration which contained twenty per cent beef heart and eighty per cent fish seemed to be taken most readily. An exclusive diet of ground shrimp did not prove satisfactory, at least the fish while on this diet became weakened and parasitized, but recovered quickly when the diet was changed. Other bass culturists do not appear to have had bad results from feeding shrimp.

It might be thought that the presence of Daphnia in the rearing ponds may prevent the young fish from taking to the artificial foods. We have not been troubled this way. Some of the fish learn to take the artificial food readily and stay in the deeper water at the lower end of the ponds. The smaller fish remain along the edges and at the head where the water is shallow. These smaller fish feed on the Daphnia drained into the pond, and as they are given artificial food at the same time, they learn to feed on the artificial food also.

During the first two or three weeks of feeding one man spends all his time on one half-acre pond. By this slow and careful feeding, all fish in the pond are given a chance to come in contact with the food and the ones that do not receive the new food readily are given special attention. Later, when the fish are taking the food readily, one man feeds two ponds, alternating between them, thus feeding about four times each day in each pond.

TABLE 2. SUMMARY OF DATA ON REARING PONDS

| Pond No. | Area in Acres | Rate of Stocking per Acre | Yield per Acre (No. fish) | Yield per Acre (Pounds) | Per cent Survival | Ave. wt. in oz. per 100 fish at end of period | Growth Period (Days) | | Average Temp. F.° | Feed Used (Pounds) | Pounds feed to produce One Pound Bass |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .569 | 100,703 | | | | | 44 | | | | |
| | | | 6.412 | 28.7 | 14.7 | 7.15 | | 67 | 73.9 | 278 | 8.4 |
| 2 | .581 | ——— | | | | | 23 | | | | |
| 3 | .592 | 100,929 | | | | | 41 | | | | |
| | | | 3,254 | 24.9 | 6.5 | 12.2 | | 64 | 75.4 | 368 | 14.8 |
| 4 | .603 | ——— | | | | | 23 | | | | |
| 5 | .614 | 50,695 | 23,045 | 329.3 | 45.4 | 22.85 | 107 | | 71.12 | 1,300.75 | 6.43 |
| 7 | .638 | 53,163 | 17,014 | 373.8 | 32 | 35.15 | 116 | | 70.43 | 2,662 | 11.1 |
| 9 | .262 | 50,000 | 29,290 | 512.1 | 58 | 27.9 | 118 | | 70.32 | 1,201 | 8.9 |
| 10 | .263 | 50,000 | 29,790 | 513.2 | 59 | 27.56 | 118 | | 70.32 | 1,413 | 10.4 |
| | | Fingerlings | | | | | | | | | |
| 6 | .627 | 10,015 | 9,494 | 171.7 | 94.7 | 28.9 | 44 | | 67.9 | 727 | 9.5 |

Pond No. 1 stocked and fish allowed to use pond No. 2 after disease set in.
Pond No. 3 stock and fish allowed to use pond No. 4 after disease set in.
Golden shiners in Pond No. 2.
Goldfish in Pond No. 4.
Pond No. 6 stocked with two-inch fingerlings, which explains the high survival rate of 94.7%.

Table 2 gives detailed figures on the production of our ponds for the 1933 season. I will not discuss this table other than to mention that the number of pounds of food required on the average to produce one pound of bass has been estimated to be about nine pounds for an average water temperature of 70° F. The foods that we used cost us on an average of three and one-half cents per pound delivered at the hatchery. This cost includes cold storage charges and trucking. Thus, the cost of producing one pound of fish is 31.5 cents.

Like all other fish, bass have their enemies and diseases. Many nests in the spawning pond were destroyed by what appeared to be fungus. In some cases the eggs on the nest would be six days old before the fungus would show up, while in other instances it would appear on the eggs a short time after they were deposited and gradually spread over them until every egg on the nest was covered. The reason for this occurrence was not known. However, a few theories were advanced, such as the water supply, the condition of the brood stock, the care which the males gave the nests, and poor eggs. My observations indicate that in nearly all cases the fungus growth was coincident with the desertion of the nest by the male. Whether there was any cause and effect relationship here I do not know.

There seems to be a period in the development of young bass much like that in trout and goldfish which is termed the "critical stage." This period occurs at about the one-inch size when the fish are in a transitional stage—changing from small food organisms to the artificial food. The resistance of the fish to disease at this time apparently is greatly decreased. This lowering of resistance may be due to insufficient food or an unbalanced ration.

During 1933 an outbreak of *Ichthyophthirius* occurred when the fish were at this critical stage. The epidemic occurred in two ponds that were stocked at the rate of one hundred thousand per acre, in which the fish had consumed all the Daphnia and had been fed ground shrimp for about one week. Some tail rot appeared at this time and a *Stentor* like protozan was in great abundance. After the diseases had run their course, the surviving fish did well, but there were very few left. This year other diseases occurred at this period and on the same date. *Cyclochaete* and the gill worm *Ancyrocephalus* were the worst forms. Very few *Ichthyophthirii* occurred and the *Stentor* like forms were not thought to cause injury. Some of the fish were treated with potassium permanganate in troughs and two ponds were treated by Dr. Hess's method,* which seemed to kill the organisms involved. A solution of one to two hundred thousand used for a period of one and one half hours at a water temperature of 70° F. killed *Ancyrocephalus* and *Cyclochaete* without the fish showing any sings of distress.

## Discussion

Mr. Langlois (Ohio): Mr. Kingsbury has apparently had some trouble with loss of fish by dragon fly larvae. We in Ohio have lost a good many fish in that way, and we also have used his system of liming the moist places in order to eliminate this larvae. The dragon fly larvae which cause the damage are mostly the *Anax junius,* which require a second season to attain a sufficient size to kill the fish. It therefore becomes necessary to keep the dragon fly larvae from passing through the winter; the ones that are produced in a single season are not detrimental; in fact the fish feed on them. The system of using lime is a very effective one if you wish to drain your pond, but in the case of your ponds that you do not care to drain, the method of control is another problem. Last winter we had a series of six ponds at Piqua, Ohio, where the dragon fly larvae had made their appearance this year. In one of these ponds we had bluegill breeders wintered over; in another we had bullhead breeders, and in two of them we had goldfish adults; in another we had smallmouth bass adults. The significant observation was made this year that the dragon fly larvae were exceedingly abundant in all the ponds except the two ponds in which the goldfish had been wintered. In all the other ponds there were *Excuviae* by the pailful, but in the two ponds in which the goldfish had wintered, not a single dragonfly emerged. So it appears possible that goldfish are an effective means of eliminating the dragon fly larvae.

Mr. Kingsbury states that it is desirable to maintain the daphnia in order to feed the young bass with the progress of the season. It is my opinion that there is an element of danger in that, because the fish which change to taking ground fish grow more rapidly than fish which continue to feed on daphnia. If there are daphnia there, your fish will tend to continue feeding on them until they are three or four inches long. If you can change all the bass in the pond

*Hess, Walter N. 1930. Control of External Fluke Parasites on Fish. Journ. of Parasitology, Vol. XVI, pp. 131-136.

to taking ground fish at the same time, I think their growth from that time on will be uniform.

Mr. Kingsbury made the comment that some of his bass go into the deeper water at the lower end of his pond, while the little fish that continued to feed on daphnia remained at the upper end in the shallows. I think that offers optimum conditions for the development of cannibalism. One thing you have to do if you are to have success in producing your fish in a bass pond is to have all the fish in the pond feeding on the same food all the time and ranging over the entire pond. In the last analysis the production of bass in a pond is just the measure of how successful you have been in preventing cannibalism.

In connection with the kinds of food that are desirable, we have this year for the first time experimentally canned a batch of carp. We put up a number of carp seined from reservoirs in cans that hold about eight pounds. We started by using these canned fish only at certain of the fish ponds, intending to get a check on the comparative value of canned fish as against the other. Before the season had gone very far, the men at these hatcheries began to ask if they could not have a little of the fresh carp; they did not think the bass were doing as well as they should. The canned carp was more pulpy than the fresh carp, and it was an excellent food on which to start the bass to taking the ground fish; but I am afraid it lacks something in food value which the fresh carp provides. So we have continued feeding the canned carp only to certain ponds, while others, run as a check, are fed on the fresh carp.

Mr. Kingsbury stated that it took about nine pounds of food to produce a pound of bass at seventy degrees. I find that varies a great deal. The larger the fish are when you take them out of your ponds, the more value you get for your investment in food.

We had trouble with *Ichthyophthirius* a few years ago, but we are not bothered with it now. My only suggestion as to a reason for that is that by forcing an early initial growth, the fish have been sufficiently vigorous to escape the attacks of it.

With regard to Mr. Hogan's paper, Mr. Hogan is using forage fish, and I cannot help but feel there is some danger in using forage fish for your bass to feed upon. The smaller bass is just another item of food the same as the smaller forage fish, and it is my opinion that the use of forage fish encourages the development of cannibalism.

Last year we discussed the deoxygenation which occurs in fish ponds at daybreak. We have had some unfortunate experiences with it this year, and Mr. Hogan has had the same trouble. It seems to me that is an inevitable result of the use of still water ponds, where you have clear water with vegetation in it. We have not had that difficulty in ponds where we encourage roil, and it is my impression that that system has its advantages. There is a definite competition between leafy vegetation and roil. In ponds where the leafy vegetation is abundant, there may be almost any number of crayfish, but the crayfish will be unable to roil the water. If we send in a crew to remove by hand as much of the leafy vegetation as they can, and stir up the bottom as much as possible while they are in there, the water becomes roily, and as far as I know that is

the most effective method of controlling vegetation. We have used sodium arsenite, and that has its place too.

In regard to the percentage of ponds to be drawn early in the season, I think that is very important. If the fish are fed in such a way that you do not have cannibalism, you can leave your pond up till the last moment before draining it.

My hatchery men also kill water snakes. I do not discourage the process, but when they kill them I ask them to open them and see what they have been eating. I know that water snakes eat fish, but most of the snakes that have been opened under my supervision have contained an abundance of tadpoles but very slim traces of fish.

Mr. Hogan got a survival percentage of seventy-one from fish that had been put in the pond as number one bass. Quite the heaviest loss that occurs in any bass pond when you transfer fry to the ponds occurs within that first two to four weeks while they are in the pond. The loss during that early period is probably due to an inadequate food supply. I do not know how early cannibalism might start, but it very often happens that when fry are placed in the ponds they simply disappear before a couple of weeks, and you cannot locate them, no matter how hard you try. When they reappear the numbers are greatly reduced, and it is my impression that that early loss is probably occasioned by cannibalism. We have had occasion to drain a few ponds after the early loss had occurred, and upon doing so we have carefully counted the fish that were put back into the pond. From that time on until the end of the season our survival percentage has been higher, from eighty to as high as ninety-five per cent. The early loss is certainly a place where we can improve our technique.

Mr. Hogan: In regard to putting fertilizer in ponds, at least with those that persist in so doing, I believe that much better results can be obtained when careful attention is given to the weather at the time of placing the fertilizer in the pond. Of course, as Mr. Langlois says, if you drain your pond the day after you stock it, you would have a higher survival. The idea with us is this: if our fish make a three inch growth and stop at that three inches, they had better be out of the pond during September than be allowed to remain in there until November and be feeding on each other.

Mr. Terrell (Wisconsin): We have had a good many inquiries recently from people who are interested in the subject of fertilization of ponds and its effects on plant growth. I would like to ask Mr. Hogan if he puts in the fertilizer while the water is in the pond, or before?

Mr. Hogan: We have followed the practice of putting it in while the water is in the pond. The reason we fertilize as late as we do is because of our ignorance, I guess you might call it, with regard to the reaction that we get from the fertilizer. If we started to fertilize early in the season, putting in five hundred pounds per acre, and then we should have a period of hot weather or some other condition arose which would result in the killing of the fish, we would be helpless to do anything to prevent it. Until we understand it a little better, if we start late in the spring, or later, and then the hot weather comes or some other condition that is bad, we have some fertilizer that is out of the ponds and does not do any damage. Many fish culturists are of the opinion that fertilizer put in late in the season is thrown away.

MR. TERRELL: Some people have poor growing conditions for plant life in their waters, and they want to fertilize the waters in order to help the plant growth. I am trying to find out how far this is practicable. I am wondering how big your largest ponds are, and whether this might prove practicable along natural lakes and streams.

MR. HOGAN: The largest ponds that we have in our hatchery that are fertilized range a little over seven acres. I see no reason why, if a person has money available for fertilizing purposes, he could not fertilize sections of a lake, a little bay or some place like that, and get good results.

MR. TERRELL: What are the proportions you use of cottonseed meal and phosphate?

MR. HOGAN: Two parts cottonseed meal to one part superphosphate. Some investigators are of the opinion that we could get along with less superphosphate which we may be able to do.

MR. EUGENE SURBER (West Virginia): I would like to call attention to a small experiment that was carried out at Leetown, West Virginia, during this past summer. We built four circular pools eighteen feet in diameter and eighteen inches in depth and supplied them with about fifteen gallons of water a minute. One of these pools was stocked with young smallmouth bass fry, and another was stocked with largemouth fry. We started both kinds of bass fry on ground beefhearts. In the case of the smallmouth bass fry we had no difficulty at all in getting them to eat the finely ground beefheart. The beefhearts were put through the grinder about ten times. One of the advantages of putting the bass in a small pond is that they are at all times visible, and if there is a loss it can immediately be seen, and if there is any cannibalism it becomes evident at once. After these fish reached a length of one and a half to two inches we changed them over from a diet of beefhearts to a diet of beef liver and Swift's beef meal. We are now feeding them beef liver and salmon egg meal in the same manner that we feed our trout. The young bass distribute themselves around the circular pool in the same way that the trout do, and swim against the current constantly, as do the trout. The largemouth bass did not take to the artificial food, yet they must have eaten a certain amount of it because they continued to grow, but at a very slow rate.

The advantage of raising bass in these small circular pools is that you have the fish visible at all times, and if any disease should break out you can readily handle it.

Another point in favor of these small circular pools is that they will accommodate a tremendous number of fish for their size. I would judge we could start at least 25,000 fry in one of these eighteen foot diameter pools. If four thousand of these young bass can be reared to a length of four inches in one of these small pools, I think it is something that should be brought to the attention of the Society, because there are places where large areas of land cannot be purchased and where an acre of land with a number of circular pools in it would be much less expensive than the larger tracts necessary for the construction of large ponds.

MR. WILSON (New York): May I be permitted to ask a question regarding

the bass? The two organizations I represent are about to enter upon that phase of raising bass. Our summer temperature averages 56° F., and our winter temperature 44° F. I wonder if someone can tell me whether it is advisable for us to go into the rearing of bass in ponds with such temperatures.

MR. LANGLOIS: We have found in Ohio that the colder water ponds are better for raising largemouth bass than the smallmouth, and if you are going to try it at all I would certainly recommend that species. But really I think the water is altogether too cold to justify any attempt to rear bass at all. Our smallmouth bass waters sometimes get as warm as 93 degrees. The warmer the water, the more growth you get.

# FLOATING BASS-BROODING EQUIPMENT

C. C. Regan
*Kentucky Game and Fish Commission*

The idea of constructing floating fish nests was struck upon during the spring of 1931 after observing the fluctuating stages of the water at Lake Herrington, Kentucky. The draw-off of water upon this particular power lake is very noticeable during the spawning season for bass. The first of this equipment to be tested by the Kentucky Game and Fish Commission was during the spring of 1933, at which time thirteen floating bass nests were placed in the lake near Kennedy's Bridge. The first nest that was put in operation, on May 12th, had a pair of bass spawning upon it within ten minutes after it was placed in the water. The longest time taken for bass to find the other nests was two days. It was found that the eggs hatched in five and one-half days with the water temperature averaging 65° at the shoreline and 62° at a depth of 6 feet.

## Construction of Floating Nests

The construction of these single floating units is inexpensive and is as follows:

Secure an empty oil or gas drum, welding to this drum four eyes from which your basket is suspended under the drum by the use of a light pliable wire. By using two eyes and suspending the basket therefrom, the agitation caused will be practically eliminated, as the drum acts similar to a fishing cork. The other two eyes will naturally swing to the top of the barrel when the basket is suspended from the two located opposite to each other. The basket or nest should be constructed thirty-four inches in length by twenty-three inches in width and four inches in depth. Material used for this basket should be one inch in thickness. Four wires should be fastened at each corner, running to two of the eyes on the drum fastened thereto—not until the proper depth is decided upon, however. The depth of the basket from the top of the water is eighteen inches, which was the most successful upon Lake Herrington. The box should have a solid bottom, keeping the young fry in the box after they have hatched and have gone down into the gravel. Native stone and gravel should be placed in the basket before launching the equipment. After this has been done the drum supporting the nest may be towed to any spot chosen by the propagator and there anchored.

## Floating Bass Hatchery

With the floating nest making the splendid showing that it did, thoughts were directed toward the construction of a pool resting within a pool in which the bass nests could be used for holding the

fry when hatched. For that reason the first floating fish hatchery came into being by the use of oil drums placed side by side under a four foot walkway which surrounds a cribbed pool four feet six inches in depth, twenty-five feet by sixty feet in length, and having a solid wooden bottom. The cribbing along the sides and ends is placed one inch apart in order that the water may circulate, also giving smaller fishes an opportunity to come through and supply natural food for adult bass being held for breeding purposes.

The above mentioned pool in this project has been subdivided into four divisions, each twenty-five feet by 15 feet in size. When the brood fish are placed in the brood pools in the spring, copper screens, sixteen-gauge, are slipped into place along the inside of each pool so as to prevent the passage of fry from one pool to another or getting out of the enclosure. In each of the twenty-five by fifteen foot pools six nests were suspended from 4 x 4's anchored to the floor and the partition dividing each pool. These nests can be trapped or may be moved at any time when the brood fish have spawned and produced their brood, after which they may be liberated. Fertilizing the pools is easily accomplished, as is the production of Daphnia in pools built of solid material and anchored around the outside of the float. Upon one end of the float is a store room in which equipment may be stored, also a small room for the keeper.

Where the hatchery rests toward the shoreline walkways have been constructed, supported by a drum, which holds the equipment away from shallow water. By the use of two windlasses, steel cables are run through pulleys and fastened to the shore, holding the float stationary, also taking care of the rise and fall of the water during flood and drought stages.

The floating bass hatchery and bass nests have been patented and copyrighted by Max Latimer of Danville, Ky. From him blue prints and a description may be had.

## Results for 1934

On April 20th, 1934, forty-six adult brood fish were placed in three of the twenty-five by fifteen foot pools, with an additional thirteen fish being placed in the other pool.

The first bass spawning was observed on May 7th, and by May 17th fifteen of the eighteen nests in the three pools had been used. Six nests anchored on the outside were taken by wild fish by June 1st. The fry produced on these outside nests were trapped and transferred into the holding pools of the hatchery. In completing the check-up of fry transferred to holding ponds and the ones liberated in the lake, it was found that approximately 60,000 bass fry were produced in and around this hatchery.

At the time this project was constructed the cost was $2,100.00, which is less than the cost of maintaining an attendant at one hatchery

for one year. These pools did not require the attention of a man at all times. If there is an abundance of natural forage fish in the body of water where it is located, the brood fish will be able to secure the larger portion of necessary food from minnows passing through the cribbing of the hatchery. One of the important parts that this type of hatchery will play in fish culture is that water shortages will never be felt so long as there is water in the stream or lake in which it is located.

By the use of this floating equipment, it is our belief that the cost of bass production will be cut down materially, and that a stronger fish will result for planting in the water in which it originated.

# THE SOCIAL BEHAVIOR OF BASS IN REARING PONDS

T. H. LANGLOIS

*Chief, Bureau of Fish Propagation, Ohio Division of Conservation*

Rearing bass to be large-sized fingerlings before placing them in natural waters involves one of two things, namely, speeding up their rate of growth or holding them longer before planting. It is a simple economic fact that two crops constitute a greater return on the investment than one, and if a crop of satisfactory bass can be harvested from each pond each autumn it is more desirable than a crop from every second pond. Accordingly, bass culturists, as a general rule, have been attempting to rear young bass to the greatest possible size in a single season.

The principal problems involved in rearing bass have to do with the provision of food, and the chief complication to the solution of the food question is the fact that a hungry bass regards every smaller bass as a possible item of food. Three main plans have been evolved for feeding bass and all are hindred by this faculty of the bass. One plan involves the application of small amounts of fertilizers at regular intervals throughout the season (Meehean, Transactions for 1933, pp. 103-109), with the bass feeding upon the zooplancton produced in a short cycle from the fertilizers. Hogan (Transactions for 1933, pp. 110-119) also used this plan but states that the bass feed to a certain extent directly on the fertilizers as well as upon the zooplancton. A second plan also utilizes fertilizers but adds certain species of fish which are physically inferior to bass and are placed in the pond for the bass to eat. The third plan (Langlois, Transactions for 1933, pp. 391-403) utilizes fertilizers to produce zooplancton for the bass to feed upon during their first three weeks, and involves providing an external food supply for the rest of the season. The best plan has not been agreed upon, and, to paraphrase Pope,

> "'Tis with our methods as our watches; none
> Go just alike yet each believes his own."

Bass fry are transferred from the breeding pond to the rearing ponds when they swim up from the nest, and are ready to begin eating. We are still attempting to provide them with living water fleas for their first three weeks, and it is my opinion that this method is not wholly satisfactory, for the biggest reduction in numbers takes place during the early period in the rearing ponds. (See Table III.) This problem remains to be solved, and it is my desire to try placing the fry in troughs and hand feeding them from the start.

After this first short period we provide the bass with an external food supply, namely, ground carp, and, as I have shown in previous papers, this system is most successful in narrow, shallow, clear water

TABLE 1. SURVIVAL OF SMALLMOUTH BASS IN REARING PONDS

| | | | EARLY SEASON | | | | | | LATE SEASON | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm | Year | Pond | Date In | Date Out | Days In | No. In | No. Out | Surv. % | Date In | Date Out | Days In | No. In | No. Out | Surv. % |
| | | | (Fry) | (Fry) | | | | | (Fingerlings) | | | | | |
| Newtown | 1933 | 17 | 5-31 | 8-15 | 77 | 50,000 | 345 | .7 | 8-15 | 10-1 | 48 | 345 | 336 | 97.4 |
| Newtown | 1933 | 4 | 5-22 | 8-11 | 82 | 3,500 | 1,466 | 41.9 | 8-12 | 9-28 | 48 | 1,466 | 1,397 | 95.3 |
| Newtown | 1933 | 5 | 5-26 | 8-24 | 91 | 10,000 | 7,109 | 71.1 | 8-24 | 10-2 | 40 | 5,181 | 4,853 | 93.6 |
| Newtown | 1933 | 6 | 5-26 | 8-23 | 90 | 12,000 | 6,179 | 51.5 | 8-23 | 10-2 | 41 | 5,605 | 5,254 | 93.7 |
| Newtown | 1933 | 7 | 5-26 | 8-22 | 89 | 14,000 | 5,178 | 37. | 8-22 | 10-3 | 43 | 7,522 | 6,856 | 91.1 |
| Newtown | 1933 | 12 | 5-19 | 6-22 | 34 | 18,000 | 12,111 | 63.9 | 6-22 | 9-12 | 82 | 12,111 | 10,547 | 87.1 |
| Newtown | 1933 | 13 | 5-19 | 8-30 | 104 | 16,000 | 7,864 | 49. | 8-31 | 9-23 | 24 | 5,731 | 5,712 | 99.6 |
| Newtown | 1933 | 17 | | | | | | | 9-8 | 9-18 | 11 | 7,582 | 7,543 | 99.5 |
| Newtown | 1932 | 11 | 6-4 | 7-1 | 28 | 19,505 | 6,238 | 29. | 7-2 | 10-2 | 91 | 6,238 | 5,318 | 85. |
| London | 1933 | 12 | 5-19 | 8-14 | 88 | 25,000 | 669 | 2.7 | 8-15 | 9-23 | 40 | 669 | 668 | 99.9 |

ponds, and in turbid water, deep or square ponds (Langlois, Transactions, 1933, p. 397). It has been found that successful production accompanies successful domestication and by domestication is meant the adaptation of the fish to regular and constant dependence upon the external food supply. In some ponds domestication has not been possible, and in those ponds satisfactory production could not be attained, while good crops were harvested from the ponds whose fish did adapt themselves to the external food supply. Discovery of the factors interfering with domestication became, therefore, a matter of paramount importance in order to enable us to accomplish domestication in all ponds.

Consideration has been given to the various features constituting bass habitat in rearing ponds, and, after settling upon types of ponds wherein domestication can be accomplished, an explanation became apparent. The factor which is now assigned such importance is the psychological response of bass to bass. This is what determines the nature of the social behavior of all bass in the pond, and domestication simply indicates the social integration of all bass in the pond, while the failure of domestication indicates the lack of social integration. Integration is an indication of the universal attitudes of toleration and fearlessness, and the lack of integration indicates the fact that certain individual bass are dominant to certain others. The occurrence of superiority and awareness of it, and of inferiority and awareness of it, in the case of bass leads to cannibalism, and fear of being eaten is sufficient motive to prevent little fish from swimming freely with big fish.

The phenomenon of cannibalism in bass ponds has been known for decades, and yet, as far as I can discover, it has not been studied as a phase of social behavior with the object of preventing its occurrence. Recognizing cannibalism as the inevitable result of the occurrence of superiority and inferiority, with the social attitudes engendered by these psychological conditions, control of cannibalism becomes a matter of preventing the development of the psychological conditions of superiority and inferiority. Competition between two individuals for some definite need or desire, with one winning and the other losing is probably the only way one can attain a psychological edge over the other. The two things wanted most by young bass are food and individual shelter, and it is competition for these items that leads to superiority and inferiority.

The three plans for feeding bass briefly described above differ in their methods of attempting to meet the desires of young bass for food and shelter. The systems of Meehean and Hogan, parts of which are used generally elsewhere, consist of providing an internal food supply which the bass utilizes and of providing individual lurking places for all. The system used in Ohio involves use of an external food supply and attempts to eliminate all lurking places.

This system involves the use of meat, cut or ground to meet the

changing requirements of the bass as to size, and cast to the water for the bass to eat at intervals of time gauged to meet the changing needs of the bass as the season progresses. It is essential to the successful use of this system that the bass be able to see the food and feel free to go and get it. The presence of vegetation in a pond interferes with successful feeding of this type in at least three ways: (1) it provides mechanical obstruction to free vision for bass, preventing them from seeing the feeder or the food; (2) it presents mechanical obstruction to free mass swimming, preventing the coalescence of individuals and small groups into the one large social group, and restricts the range of the individuals of small groups to limited parts of the pond; (3) it provides individual lurking places wherein certain individual bass develop the "king in his own domain" feeling that leads to superior individuals so detrimental to the welfare of the mass. The explanation of successful domestication of bass in the two types of ponds described above is that in these ponds vegetation could be controlled and it was possible to get the fish to rely entirely upon the external food supply.

This system has the following merits: (1) By its use we are able to obtain satisfactory quantities of fish from our small-area ponds (Tables 2 and 3); (2) the bass reared by this method attain a satisfactory size in a single season; (3) the use of ponds of the types described, where the vegetation is kept under control, makes it easier to handle the fish and the fish are injured less in handling.

TABLE 2. PRODUCTION OF BASS IN SMALL-AREA PONDS, USING EXTERNAL FOOD SUPPLY

| Year | Farm Number | Pond Number | Acres | Number of Fish | Weight in Pounds | Pounds of Food |
|---|---|---|---|---|---|---|
| 1933 | 7 | 2 | .476 | 3,348 | 217 | 1,469 |
| | | 3 | .451 | 7,521 | 480 | 3,679 |
| | | 4 | .469 | 2,858 | 362 | 3,298 |
| | | 5 | .469 | 8,363 | 529 | 4,165 |
| 1932 | 8 | 2 | .356 | 5,304 | 520 | 3,683 |
| | | 3 | .368 | 5,743 | 634 | 3,793 |
| | | 4 | .376 | 3,542 | 385 | 2,397 |
| 1932 | 9 | 2 | .643 | 15,440 | 1,011 | 5,409 |
| | | 3 | .562 | 4,464 | 506 | 2,511 |
| | | 4 | .562 | 4,241 | 270 | 2,024 |
| 1933 | 9 | 1 | .602 | 8,500 | 1,027 | 3,989 |
| | | 2 | .643 | 2,735 | 477 | 2,358 |
| | | 3 | .562 | 7,754 | 883 | 4,525 |
| | | 4 | .562 | 5,389 | 598 | 4,098 |
| | | 5 | .241 | 1,771 | 279 | 2,187 |
| 1930 | 2 | 4 | .600 | 2,863 | 462 | 2,148 |
| | | 7 | .550 | 16,000 | 1,199 | 5,074 |
| 1931 | 2 | 4 | .600 | 9,172 | 765 | 3,063 |
| | | 8 | .430 | 6,156 | 471 | 2,781 |
| 1932 | 2 | 7 | .430 | 3,693 | 502 | 3,112 |
| | | 9 | .360 | 10,129 | 1,030 | 5,261 |
| | | 10 | .360 | 12,520 | 700 | 3,773 |
| | | 12 | .391 | 5,206 | 537 | 2,388 |
| 1933 | 2 | 2 | .230 | 1,313 | 108 | 1,227 |
| | | 10 | .430 | 5,007 | 411 | 2,783 |
| | | 11 | .360 | 9,543 | 707 | 5,890 |
| | | 12 | .360 | 10,547 | 731 | 5,413 |
| | | 14 | .330 | 9,531 | 613 | 4,965 |
| | | 15 | .320 | 9,664 | 589 | 4,538 |

TABLE 3.

| | |
|---|---|
| Number of fish per acre | 15,147 |
| Pounds of fish per acre | 1,299 |
| Pounds of food per pound of fish | 5.999 |
| Average weight per fish (ounces) | 1.3718 |
| Average length (inches) | 5⅜ |
| Number of ponds | 29 |
| Average acreage per pond | .451 |

## Discussion

Mr. Stobie (Maine): I would like to ask Mr. Langlois what was the size of ponds they used, and the amount of water that goes through the ponds?

Mr. Langlois: We have modified our ponds, splitting them up and putting levees through them; the ponds we have split up in that way range from thirty to fifty feet in width, while the length, which is not so important, ranges from a couple of hundred to four hundred feet. We are building some new ponds at the present time which will have a surface width of about fifteen feet and will be three to six hundred feet long. An eight inch pipe carries the water from this series of ponds, and it is my impression that the use of this amount of water in ponds of this shape will give much more current in a narrow raceway of this type than if you had the same volume in a large rectangular pond.

Dr. Embody (New York): I am interested in what Mr. Langlois said about the crayfish exterminating the coarse aquatic plants. I would call attention, however, to the fact that there are a good many species of crayfish, and I would like to have the name of the particular species that does the work in Ohio so satisfactorily. Ohio and all the Mississippi valley states are much more abundantly supplied with crayfish than the eastern states. I find that our own local form, *Cambarus bartonii,* does not operate the same as Mr. Langlois'; it does not seem to exterminate the vegetation. It simply has no effect on the pond, except that in a great many cases it will follow up the drain pipes and cause a bad leak. A few years ago Mr. H. C. White of Canada brought in a Canadian crayfish; I cannot tell you the name of it, but I am going to submit specimens to a specialist to see if we can find out what its name is. This crayfish operates in exactly the same way as the one described by Mr. Langlois. It propagates enormously; it has a much higher reproductive capacity than any other crayfish we have tried. It is never very hard-shelled. It grows to a size of about an inch or an inch and a half in one summer, and it completely exterminates the vegetation in our ponds. It does not, however, in all cases make these ponds roil; some of the ponds are just slightly turbid after these crayfish have operated. They exterminate the very weeds that give the most trouble, that is, the common Elodea, and do so more effectively than any other method we have tried. They exterminate nearly all pond weeds, but they have not such a great effect upon the American milfoil, which grows so abundantly in some places.

Mr. Langlois: I have had our crayfish identified; I am sorry that the name slips my mind, but I shall be glad to send it to you, Dr. Embody. Later in the season, when we drain our ponds, we take crayfish out by truckloads and place them in natural waters as a supplementary food supply. We took out over 400,000 crayfish that way last year.

# THE ROLE OF FERTILIZERS IN PONDFISH PRODUCTION

## II. SOME ECOLOGICAL ASPECTS

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The use of fertilizers in ponds to increase the production of fish is not new, yet no accurate scientific information has been derived for the intelligent use of these products. The gathering of such information would involve coordinated study, over a long period of time, in the fields of chemistry, bacteriology, and biology.

In the South, during the past two or three years, we have made an attempt to find the most suitable fertilizers for the improvement of bass production and to determine the effect of them upon the ecology of the pond. In this connection products from various sources have been utilized. These products have been tried in varying amounts up to the extreme point of pollution where the dissolved oxygen has been reduced to approximately one part per million.

This study has been carried on from an ecological point of view using the chemical analyses as measures of control in so far as they indicate the amounts of various substances such as dissolved oxygen, pH, and dissolved phosphorus in the water. It has revealed that there are certain fundamental ecological relationships operating in the ponds. If fertilizers are to be used successfully these relationships must be given consideration. Since the observations have been made under southern conditions, they probably are not wholly operative elsewhere.

Whereas the pH of the water may reach 9.4 to 9.5 in Iowa and Illinois, it is not unusual, during the summer, for it to reach 10 in Oklahoma and Louisiana and for the dissolved oxygen to be far above saturation. This indicates that the ponds have a capacity for the utilization of fertilizer that will not be found in any other climate. These observations have led to the use of the "organic" type of fertilizers such as cottonseed meal, animal tankage, and blood meal. There are no data to indicate that commercial fertilizers like ammonium nitrate or "nitrophoska" would have a similar effect upon a pond. This problem has received some consideration this year but the data are not yet complete.

The production of plankton organisms in maximum numbers takes place when organic matter is available in suitable quantities. In the northern sections of the United States this occurs soon after the water begins to warm up and about the time the fry begin to appear. Recurring pulses of zooplankton may continue intermittently practically through the whole season. In the South the swarms die out early in the spring and do not reappear during the summer. Since the development of zooplankton is dependent upon available organic materials, the cycle may be stopped at any point by a curtailed food supply.

Hence the ponds may be classified by the presence or absence of certain organisms as to their capacity for the production of bass.

The first forms to appear when the pond is flooded, or with the influx of organic materials, are protozoa, rotifers, and immature copepods. These are undoubtedly dependent upon the more fundamental food supply found in bacteria which, in turn, have been stimulated to reproduce rapidly by the increase in organic substances in the water. Observations indicate that these pioneer organisms may be stimulated to reproduce by the addition of fertilizer, by the killing of weeds in the pond with sodium arsenite, or by any other method that will make food available to them. Should there be a limited amount of organic substances the plankton cycle may stop at this point.

The next forms to make their appearance are the zooplankton crustacea such as *Daphnia, Scapholeberis,* or *Simocephalus.* They cause a rapid decrease in the number of pioneer forms and may reproduce rapidly enough to form immense swarms around the shores of the ponds. Their abundance is dependent upon the amount of available organic material so that they may be stimulated to develop by the regular application of fertilizer until other inhibitory conditions develop. In the South these may be ordinary summer conditions, the accumulation of waste products, or an unwarranted increase in the amount of vegetation, such as rooted plants or filamentous algae, to a point where the food supply is cut down.

As the season advances the plankton crustacea decrease in numbers and the population at the bottom of the pond begins to increase. The organisms in this group include *Macrothrix, Leydigia,* and various ostracods. Chironomids become larger in size and more abundant and the various nymphs begin to appear. The presence or absence of large quantities of vegetation determines, to some extent, the amount of food available for the various organisms and may therefore limit the bottom population. A smaller number of weeds in the pond affords sufficient habitat for the various types of nymphs and does not make too great a demand upon the fertilizing substances. It is to be remembered, in considering the dominant organisms that have been mentioned here, that any or all of the others may be present and make up a larger or smaller share of the food supply for fish.

Last year a study of the food found in the stomachs of fingerling bass showed that these fish take the organisms in precisely the cycle outlined above. As the size of the fish increases, the selection of food is shifted to larger and larger organisms, and the amount of growth that takes place is somewhat in proportion to the number of food organisms of certain types available. Just what this relationship is has not been determined fully, but there is good correlation between certain food organisms and fish production. I have never been able to find a definite correlation between the total bottom fauna and fish population as some of the German investigators have been able to do for their lakes.

All of the major food organisms that we have taken from the stomachs of bass up to two to two and one-half inches grow best where the organic matter is highly concentrated. *Daphnia* and *Simocephalus* find an ideal habitat in highly polluted* pools. Chironomids grow well in polluted water where the organic matter has been somewhat stabilized. Both grow in heavily fertilized ponds where the dissolved oxygen has been cut to a minimum. Experiments last year showed that fingerling bass are able to live and thrive in a habitat heavily polluted with cottonseed meal because of the large amount of food available.

These high concentrations of fertilizer are, however, sufficient to kill the adult bass in the pond and are inimical to breeding conditions. The presence of fish in a habitat is usually correlated with spawning conditions. Relatively clean water, high oxygen, and suitable bottom are necessary during the breeding season, while food is a secondary consideration. Low oxygen in the brood ponds is sufficient reason for a poor hatch. From the data this year, indications are that it will be necessary, if we are to fertilize heavily, to reserve certain unfertilized ponds with a minimum of vegetation for breeding purposes.

Studies of the environments suitable for aquatic nymphs, such as the *Odonata* show that they also do not thrive well in ponds that are heavily polluted. These are the food upon which the larger fingerlings must depend because the smaller types, such as ostracods, certainly do not furnish an adequate supply for four inch bass.

Probably the future of successful pondfish culture will depend upon the correct balance between breeding and food conditions whether it be maintained within a single pond or by use of a series of ponds. In the South this calls for a modification of the ideas on fertilization that have been developed in the last couple of years. It will be necessary to strike a balance between the heavily fertilized ponds which will carry a large number of fish to two or two and one-half inches without forage food, and either lightly fertilized ponds which will produce larger food for a more prolonged season, or space must be found to produce an adequate supply of forage minnows.

In Louisiana we may fertilize the rearing ponds heavily and drain them by the first of June before the hot weather sets in. In such a case the production per acre may run very high and the fish reach about two inches in length. These ponds could be utilized, during the remainder of the season, for sunfish and catfish or others that require a longer growing season and hatch later. The other alternative will be to fertilize less and produce a large number of forage minnows to carry the fish through the summer, and drain the ponds in October and November, taking out a smaller crop of bass eight to ten inches in length.

*The words "polluted" and "heavily fertilized" will be used interchangeably here since they are one and the same thing. All data refer to largemouth bass.

## Summary

It has been shown that the life cycle within the pond runs in definite order from smaller to larger organisms, and that each succeeding group is dependent upon the preceding one for the synthesis of its food supply. The animal cycle occurs precisely in the order that makes it suitable for bass food, since it coincides with the ability of the fish to take larger and larger organisms. The abundance of these organisms is dependent upon the amount of available organic matter in the water. This can be controlled by the use of fertilizers.

Heavily fertilized ponds are not suitable for the maintenance of brood fish and are inimical to good spawning conditions. Separate unfertilized ponds must be maintained for the successful breeding of bass.

In the South the food supply of the bass is shifted permanently from the plankton to bottom organisms early in the season. It is upon the type of food that we expect to grow on the bottom, and which can be controlled by the use of fertilizers, that our future policy concerning their use will depend. In heavily fertilized ponds the food cycle will probably end with the chironomids, which will support fish to about two inches adequately. This limits the production to a larger number of smaller fish. The larger nymphs necessary to carry the fish through the summer prefer cleaner water. If the latter course is followed, we must make provision for the production of supplemental forage food.

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# AN INEXPENSIVE BALANCED DIET FOR TROUT AND SALMON

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## A. Introductory

Prior to 1933, the State of New Hampshire, undoubtedly like many other states, was using at her fish hatcheries a rather costly food for trout and salmon. This food was about five and one-half times more expensive than the trout and salmon food, described below; the old food was not as nutritive as the new food; it was often diseased and charged with pathogenic bacteria, especially the beef liver; herring preserved in salt often arrived soft and decomposed and unfit as food for salmonids; large adult Silver Hake was also used. The quality of the fish-ingredient of the old trout food, although one-half cent less in price than that of the fish-ingredient of the new food, was often such that it more than negated this favorable feature, and, therefore, much of the old food was, more or less, a loss.

My thought was that it was quite within our powers to get a food for our fish perfectly fit for human consumption, as all food for game fish should be, a food that would be perfectly safe from a health standpoint, more nutritive, and relatively and absolutely less expensive.

Accordingly, as soon as the old contracts expired, and the opportunity presented itself, it was ascertained, as expected, that young fish of a number of species, ranging in length from three to twelve inches, could be obtained freshly frozen and in any quantity desired at circa one to one and one-half cents less per pound than the then prevailing price for adult "Whiting" (Silver Hake) and large salted herring commonly used.

It was conjectured that large adult fish of a single species, such as Silver Hake, did not constitute a balanced diet. This opinion was based on the known biological fact: The adult organism, while in its living state may itself be in physiological balance, does not, nevertheless, constitute a balanced diet to young fingerling trout, because such old fish are too specialized chemically and morphologically; on the other hand, younger fish of the same species may be sufficiently variable quantitatively and qualitatively so as to constitute a balanced food for young growing fish.

It was proved by feeding, that one and one-half-inch fingerling brook trout (*Salvelinus fontinalis*) became sick and commenced to die rapidly after having been fed on adult Silver Hake for about two weeks. They recovered when fed on a balanced food such as that described below. Whereas, young fingerlings of the same kind, age, and size,

which were fed exclusively on a mixed fish diet (composed of small fish of a number of species) did not develop any symptoms of illness. It was found that it is safer to feed young fish on a mixed fish diet of a number of species, than on small fish of only one species. While in the latter case, no ill effects may be noticeable for a time, it cannot continue in this manner indefinitely. This is due to the fact that a given species of fish, containing a great deal of its own formative tissue, differs chemically from another species of the same relative age and size and physical make-up, and therefore, a mixture of such varieties of foods provides for a food having the necessary balance to satisfy the requirements of a constantly changing metabolism of the growing organism.

The new food, described below, gave very wonderful results. This was evidenced by the extraordinary growth attained amongst brook trout (*Salvelinus fontinalis*), rainbow trout (*Salmo irideus, S. shasta, et al.*), brown trout (*S. fario*), lake trout (*Cristivomer namaycush*), chinook salmon (*Oncorhynchus tschawytscha*), Atlantic salmon (*S. salar*), and in the landlocked salmon (*S. salar sebago*), at the Summer Brook station in Ossipee and at the Warren hatchery, where the new food was prepared and fed scientifically. By the middle of October, out of 500,000 brook trout at these two stations, about 200,000 were 7.5 inches in length in less than 10 months since the time of hatching. Chinook salmon, only five months old since it commenced feeding, was about ten inches in the same proportionate number as there were 7.5-inch individuals amongst the brook trout. At New Hampton, the percentage of past legal size brook trout of the same age was not so high because of periodic interruption in the methods of preparing and feeding the food to the fish. In former years, fish of the same age were always spoken of in terms of "fingerlings"; but in 1933, the fish reared on the new trout food were of legal size before they were ten months old. They were very attractively colored, showing the red spots already when four inches long, and the white borders of the pectoral, pelvic and anal fins, just as in the most attractive adults.

Of course, the best food for trout and salmon is natural food. In general, fish live on fish. But the youngest of fish, as a rule, do not live on fish. Crustaceans and young insects, their larvae, microscopic algae, protozoa, macroscopic metazoa and embryos of higher forms are their basic food. Such food in quantity is at present impractical for trout culturists to provide. The reason why beef liver has proved to be the generally accepted "best trout food" is due to the fact that liver of mammals, as an organ, happens to correspond more closely in chemical structure to the whole body of a young organism, than any other organ in the body of an adult organism, with the exception of the gonads; the liver of beef and sheep or hogs is perhaps better trout food than most other ordinary trout foods used, although of these three types of liver, the last named is the poorest. Ripe roe (ovaries), and gonads in general, would, of course, be much better than mammalian

liver, but the former is often in insufficient quantity on the market, and the latter, while it can be obtained in quantity, is now too expensive. Furthermore, beef liver gives a dull and unnatural color to trout and an unpalatable taste to the fish, if used as food for the fish until such fish are prepared for the pot. Gonads, with the exception perhaps of salmon eggs, when on the market, are, indeed, too expensive for trout food at the present time. More than two-thirds of mammalian liver is water; less than one-third is food; the rest is ashes. On a solid basis, when the price of beef liver is 8.5 cents per pound, the cost of its solid, the food itself minus the water, is more than 25.5 cents per pound. This is a conservative estimate, for the food volume per pound of raw liver is nearer one-fourth of a pound than one-third. Determined on the latter basis, the cost of a pound of solid food present in beef liver at 8.5 cents per pound of raw liver is actually 34 cents. In reality, this is the real price of the trout food when beef liver is used. If transportation cost is added to this, the cost of such trout food is, of course, even higher!

I have found a better and less expensive food for trout and salmon of all ages than beef, sheep or hog liver, or the combinations of any other common trout food used. This new food resembles the natural food of trout and salmon more closely than any other foods for salmonids used so far.

This food consists of assorted fish of any six or all of the following species, none of which must be over 12 inches, preferably less than 12 inches in length: White Hake (*Urophycis tenuis*), Silver Hake (*Merluccius bilinearis*), Common Pollock (*Pollachius virens*), Tomcod (*Microgadus tomcod*), Common Mackerel (*Scomber scrombrus*), Tinker Mackerel (*S. japonicus*), Bonito (*Sarda sarda*), Little Tunnies (*Gymnosarda alleterata*), Common Sand Lance (*Ammodytes americanus*), Common Herring (*Clupea harengus*), Sardine (*Clupanodon pseudohispanicus*), Tailor Herring (*Pomolobus mediocris*), Alewife (*P. pseudoharengus*), Glut Herring (*P. aestivalis*), Menhaden (*Brevoortia tyrannus*), Anchovy (*Anchovia brownii,* and *A. mitchilli*), sheep liver and heart and salmon egg meal. The assorted fish and sheep liver and heart are frozen while absolutely fresh and remain in this frozen state until prepared for use in the hatchery. Neither of these foods are over six months old from the time of killing to the time when prepared for feeding to the trout. When seventeen pounds of these assorted fish, equal amounts of each species, and ten pounds of sheep liver and seven pounds of sheep heart are prepared according to the texture of the fish used and the size of the trout or salmon to be fed, and are mixed with 8.5 pounds of salmon egg meal in such a manner that none of the ingredients are lost in the water during feeding, this mixture constitutes the least expensive and the most highly satisfactory growth-producing trout food in the world. Squids (*Loligo brevis, L. pealei* and *Ommastrephes illecebrosus*), Blue Mussel (*Mytilus edulis*) and species of *Modiola* may be used too, as a part of the food or as

substitutes for fish. The Blue Mussel may be fed separately to older fish with excellent results. When ground fine to be fed to younger fish, it is best to bind up its juices with salmon egg meal on the 50:50 solid basis, *e. g.*, Mussel: meal.

The mud crabs (*Eupanopeus herbstii, Eurypanopeus depressus* and *Neopanopeus texana*), which often do great damage, when present in large numbers, to young clams, have been used as food for older fish with good results. While salmon and trout do not normally live on shore crabs, it is known that like other fish, while young, they do enjoy other crustaceans as food. However, no one knows what constitutes the food of salmon during their four years or so at sea. Do they during this period of their lives feed purely on nektonic forms?

### B. How to Prepare the Food

The fish, liver and heart are ground separately, equal volume of fish to liver and heart. These are then mixed in a wooden trough by the use of a potato hook. To this mixture is then added the salmon egg meal and the three ingredients are then well mixed with the same means as before. After this mass has been well mixed, it is ground once more through the same fine plate with one-fourth inch perforations. For fingerlings from two inches and up, only two grindings are necessary, one for the fish, sheep liver and heart, and one when the meal has been mixed with these. Coarser plates should never be used when salmon egg meal is used with the food because the finer the raw meats are ground prior to the mixing with the meal, the more thoroughly mixed will be the final mixture of the prepared food, with a minimum attendant loss of meal during feeding.

The aim sought in grinding the meal (which already is fine) with the raw meats after having mixed them well first, is to keep the meal from separating from the rest of the food during feeding. To get the proper results from the meal, there is no use of simply mixing the meal with the ground fish and liver and heart, for, such a mixture is not a mixture at all; most of the meal will fall out and be lost at the bottom as waste. For the smallest fry, fish with very small scales may be used with the liver and heart, in order to eliminate any possible clogging of the plate by the scales during the grinding. For young chinook salmon, the finest plate must be used until this fish is three inches long, because the young chinook tends to become easily constipated when fed on food which brook trout of less than that size can manage. For early fry, it is necessary to grind the meats fine first, may be two times, and then to grind the meal with the meats perhaps three times. This will make a "paste" which must be thinned out with water before using. For trout over two inches and salmon over three inches, the raw meats with their normal amount of serum, well assorted oily and less oily fish prepared with the salmon egg meal on the 50:50 solid basis, can be fed without any addition of water. This is especially true for fish over 3.5 inches. A slight addition of water may be neces-

sary at times, especially if some of the serum is lost from the liver during thawing, and the fish happens to be of the less oily types; but water should be used sparingly, particularly when the prepared food has been ground only twice (once the raw meats, and once after having been mixed with the meal), in order not to render the food too disintegrative. Properly prepared food of this kind tends to float at the surface of the water and the fish will eat it before it falls to the bottom. This precaution should also be taken with food prepared for the fry; a great deal of air is introduced into the food during the grinding and the subsequent mixing with water, so that the small air-bubbles collecting on the food particles makes them buoyant.

When crabs are available, they may be prepared fine, with the shell, and fed to adult or larger fish as an occasional meal; mussel and squids may be fed separately too, after the former have been removed from the shell, and the latter cut up into desirable pieces. When feeding mussel without mixing it with salmon egg meal it should be fed whole or nearly so, in order to preserve the valuable body juices. The less mussel is cut up, the more the total body liquids are preserved.

When fish attain the size from four to eight inches, one may be tempted to simply grind the raw meats (fish, liver, heart) once through a one-half-inch perforation plate, thereafter to mix the salmon egg meal with these chopped meats and feed the mixture directly without any further grinding. But, while the food may be more easily handled in this way, it is as such a very wasteful preparation.

(1) Because this type of preparation of the food provides for the very thing which it was the intention to avoid, *viz.,* (a) Disintegration of the food during feeding, and (b) The loss of the meal, the most important element of the food, which cannot be eaten as such by the larger fish after it falls out from the meats and drops to the bottom and is mingled with the sand and gravel.

(2) The larger fish get most of the food.

(3) The smaller fish remain small, due to irregularly obtaining food.

(4) The larger fish grow relatively much faster than the smaller fish which become progressively too small for their age; in fact, the food is too coarse for the smaller fish; they become subject to cannibalism on the part of their larger brethren.

### C. How to Feed This Food

Of course, good care should always be taken in feeding all the fish in a trough, raceway, pool or modified brook. Never just throw the food in, as is so generally practiced. *But feed the food to the fish! Take time in feeding the fish! It pays well! This is the purpose of feeding.* When feeding, wait until each morsel of food thrown in is consumed before another morsel is offered. It is of importance to scatter the food to all the fish that they may not school, especially when the fish get to be over five inches; during such schooling, induced by

careless methods of feeding, the fish will bump each other's eyes; some will get most of the food, others will go hungry.

### D. Remarks On Results

1. If good care is taken of trout and salmon during their juvenile stages, protecting them against diseases, keeping the environment clean, and by feeding them well at all times, realizing that better growth may be attained from a given quantity of food fed at two different times instead of at one time, in other words, frequent feeding to all the fish, rather than haphazard feeding at long intervals, the results obtained will more than repay for the extra trouble.

2. If the bottom is always kept clean from oxygen consuming stuffs, and algal growth be promoted, the fish will thereby get a better lien on life and become much less subject to disease. The algae in reference here is mainly non-filamentous algae. Too many filamentous algae in a pond or pool are destructive to trout and salmon, especially to fish under five inches.

3. The unusual growth, the attractive color and good health which fish attain, when cared for in the manner described above, are worthy of the aspiration of all fish culturists. The mortality rate, always much too high for trout and salmon, can be reduced practically to zero if all the little things are watched and none of them ignored or violated from the time of the taking of the eggs and all the way up through the various stages of growth and development. The food described above, properly prepared and fed, provides a much greater health coefficient in the fish than beef liver or any other trout food used.

4. To prove this: Two lots of eastern brook trout (*Salvelinus fontinalis*), 1,500 in each, were placed in separate tanks under the same water, oxygen, pH, and temperature conditions. One lot had been fed on our new trout food for six months, the other lot had been fed on beef liver. The fish were fifteen months old since the time of hatching. Both lots were placed on a diet of canned herring. Within two weeks, the liver fed fish became sick from what must be regarded as food deficiency disease; two weeks later, the other lot also got sick. The fish of both lots, the apparently still healthy, the sick and the dead as well, upon careful physical examination, looked perfectly normal in every respect, except that some were dying or had died. They were unusually fat, beautiful fish, especially those fed on the combination diet. It took twice as long to restore the liver-fed trout to a normal healthy state with no mortality than it took to restore the other lot. To restore the fish to normal health, beef liver was fed for three days and the combination diet for three days, alternately. The beautiful color obtained from the combination diet, seemingly is an indication of the presence of a "strong" chemical body. The reverse is the case in fish fed on beef liver. That this is of great economic importance must be realized when it is recognized that beef liver as a trout food is much more costly than the combination diet described above.

5. To illustrate: 150 pounds assorted fish delivered cost $5.25, 150 pounds sheep liver and heart delivered cost $7.50, total: $12.75; 75 pounds salmon egg meal delivered cost $6.38, or 8.5 cents per pound.

But the assorted fish, sheep liver and heart are three-fourths water and other wastes; only one-fourth by total volume is food, hence 300 pounds of fish, sheep hearts and liver, which cost delivered 4.5 cents per pound, actually cost, on the basis of their solids, 17 cents per pound. Therefore, for every pound of salmon egg meal used, on the 50:50 solid basis, with fish, sheep liver and heart, there is a saving of 8.5 cents. If beef liver is used, instead of assorted fish, etc., with the cost of the former, 8.5 cents f.o.b. or 34 cents per pound on the food solid basis, there is a saving of 25.5 cents for every pound of salmon egg meal used.

When salmon egg meal, which is practically all food solid, is allowed to take the room of one-half of the raw meats on the 50:50 food solid basis, every time 300 pounds of fish, sheep liver and heart are used, there is a saving of the difference between $12.75 and $6.38, or $6.37. The total cost of 375 pounds of this food mixture is $19.13. If the same amount of actual food should have been fed, using raw meats only, it would have cost two times $12.75 or $25.50; the saving attained, by using salmon egg meal, is as indicated $6.37 for every 75 pounds of salmon egg meal used on the 50:50 solid food basis of sheep liver, heart and fish.

But if, as in former years, and still to considerable extent in different states, beef liver is used instead of sheep liver and heart and assorted fish, the difference is much greater.

Three hundred pounds of beef liver cost $25.50; seventy-five pounds of salmon egg meal cost $6.38; the total cost of 375 pounds of such food is $31.88. If no meal were used, and the same volume, although not the same value, of food was to be obtained, using only beef liver, 600 pounds would be required at a cost of $51.00. The saving effected in using salmon egg meal with beef liver is the difference between $51.00 and $31.88, or $20.12; the saving effected in using 375 pounds of sheep liver and heart and assorted fish with salmon egg meal on the 50:50 solid basis, instead of beef liver, equals the difference between $51.00 and $19.13, or $31.87 per 375 pounds of the new food combination.

Hence, the actual saving per 375 pounds by using raw meats and salmon egg meal as used in Dr. Agersborg's new trout food (not counting mud crabs, blue mussels, *Modiola* and squids) is the sum of the difference between the equal food values of beef liver, *e. g.*, $51.00, and the cost of 375 pounds of Dr. Agersborg's trout food, *e. g.*, $51.00 minus $19.13, or $31.87. The saving, therefore, obtained for every 100 pounds of salmon egg meal used is the difference between the cost of the equivalent food solids for which the meal substitutes and the cost of the substituting meal. That is, when 100 pounds of salmon

egg meal take the place of 400 pounds of raw meats, the saving is the difference between the cost of 400 pounds of such raw meats and the cost of the meal.

6. In one year the expenditure for trout food was $12,600. This food consisted mainly of circa 148,232 pounds of beef liver. If this volume had been sheep liver and heart and assorted fish, it could have been delivered at the hatcheries for $6,670.44, or at a saving to the State (New Hampshire) of $5,929.66. Furthermore, since the use of salmon egg meal would require the use of only one-half of this volume of raw meats, *e. g.*, about 74,116 pounds, at a cost of only $3,335.22, and 18,529 pounds of meal, at a cost of $1,575.02, the total cost would be only $4,910.24, with a saving of $7,689.76 (the difference between $12,600.00 and $4,910.20). In other words, it is possible to rear nearly 3 times more fish on Dr. Agersborg's improved trout food than on beef liver used alone as food or in combination with one or two species of large fish.

The fact is, however, we actually reared five times more fish on less than two-thirds the cost of food compared with the cost of the previous season. But in addition to this great saving, we obtained several other intrinsic values or/and benefits besides, such as, a much more healthy fish, as compared with trout reared on beef liver, a trout that can be eaten with much real enjoyment even though it may be caught from the brook directly after having been planted there from the hatchery, a trout much more beautiful to behold than liver fed trout, and a trout with a better chemical structure which can withstand unusual dangers that it may encounter while yet under artificial confinements or/and in nature. Our saving was, therefore, not only four times $12,600 plus $5,429 or $55,829, but this sum doubled: $55,829 times two equals $111,658 because our fish were on the whole more than twice as large as fish of the same age previously reared in the State.

## Discussion

Mr. Langlois: I note that the author of this paper had trouble in connection with the food being reduced to too much of a pulp when it was run through the grinder. We had the same trouble with our fish, so that we took up with a manufacturing company the matter of developing a grinder which would not do that. The ordinary grinder has rifling in the barrel leading straight from one end to the other, and the food put in the grinder is reduced to a pulp by the action of the worm against this rifling. In the machine we have developed, the rifling is made to run in the same direction as the worm carries the food, so that the material is presented to the blades at the end of the barrel in a proper solid condition. Then, in the case of the ordinary grinder, the cutter at the end of the barrel is a cross with four blades. We use that cross for the grinding fine for the small fish, but for getting larger chunks for the large fish we cut off the opposite two blades and thus use a two-bladed cutter.

# STANDARD METHODS OF COMPUTING BASS PRODUCTION

T. H. Langlois

*Chief, Bureau of Fish Propagation, Ohio Division of Conservation*

Experiments are in progress at every bass farm in the country to determine the most practical production methods and since these experiments are uncoordinated it is desirable that bass producers compare notes for mutual benefit. Unfortunately, the data assembled lack uniformity and comparison is less valuable than it could be if all bass producers used the same landmarks. It is the purpose of this paper to call attention to this need for standard methods of computing bass production and to suggest certain places where all methods can be expressed in uniform terms. These suggestions have to do with methods of stating quantities of fish produced and the size of fish when they are taken from the ponds.

For each pond the data should include the total number and mass weight of fish produced. Since the mass weight of the total number of fish produced in a given area can be compared while the mass length cannot, it is suggested that comparisons of quantities of fish produced per common unit of volume of water can best be done by comparing mass weights. It is suggested that comparisons of quantities be referred to a common unit of volume of water rather than of surface area because ponds vary greatly in depth. Since a pond with a surface area of one acre and a uniform depth of three feet contains approximately one million gallons of water, production should be determined per million gallons of water. The items to be referred to this common unit of volume are numbers of fish and pounds of fish, and I suggest the abbreviations, FPMG for numbers of fish and PPMG for pounds of fish. The following table illustrates this method:

| | 1932 Nos. 2-9 | 1932 Nos. 2-10 | 1933 Nos. 2-12 | 1933 Nos. 2-13 | 1932 Nos. 8-2 | 1932 Nos. 8-3 | Average |
|---|---|---|---|---|---|---|---|
| Vol. in gals. | 250,000 | 250,000 | 250,000 | 250,000 | 200,000 | 200,000 | |
| Pounds out | 1,030 | 700 | 731 | 406 | 520 | 634 | |
| P. P. M. G. | 4,120 | 2,800 | 2,924 | 1,624 | 2,600 | 3,170 | 2,873 |
| Fish Out | 10,129 | 12,520 | 12,111 | 7,864 | 5,304 | 5,743 | |
| F. P. M. G. | 40,516 | 50,080 | 48,444 | 31,456 | 26,520 | 28,715 | 37,622 |

The common use of the term average length offers little or no basis of comparison because each fish culturist has his own method of determining the average length. Pond populations of bass differ tremendously in the length variations of the fish comprising them. Some populations may be portrayed by a uni-modal curve; others by a bimodal curve and still others with less definite groupings.

Only the mode of a uni-modal curve has significance in expressing average length and since this type of curve is not universal, it is not feasible to try to compare length by comparing modes or averages. This can only be done by the use of tables of figures which show variations of length and frequencies of occurrence. When dealing with large numbers of living fish it is not practical to measure everyone and the use of a representative sample is sufficient. This sample must be selected at random and it is suggested that when all fish from a pond have been gathered into a common container, the sample should be dipped from the mass. This sample should consist of a uniform number of fish and we have found that 150 fish are adequate. Each fish in such a sample should be measured to the quarter-inch and the results compiled into a length-frequency table.

Since the size attained by the fish is partly a function of its age, the age should always be indicated. Statements of the age of the fish should be of the days elapsed from the date the bass fry swim up from the nest until they are measured. The following table illustrates this method of stating size:

| | S. F. F. NO. 2 | | S. F. F. NO. 5 | S. F. F. NO. 8 |
|---|---|---|---|---|
| Length (Inches) | 1934 Pond 7 | 1933 Pond 14 | 1934 Pond 17 | 1934 Pond 1 |
| 3¼ | – | – | 1 | – |
| 3½ | 1 | – | 3 | – |
| 3¾ | – | – | 11 | – |
| 4 | 1 | – | 13 | – |
| 4¼ | 4 | – | 14 | 2 |
| 4½ | 11 | 5 | 30 | 8 |
| 4¾ | 18 | 5 | 16 | 7 |
| 5 | 30 | 15 | 16 | 10 |
| 5¼ | 19 | 18 | 15 | 14 |
| 5½ | 17 | 32 | 11 | 22 |
| 5¾ | 18 | 28 | 10 | 29 |
| 6 | 18 | 21 | 6 | 23 |
| 6¼ | 7 | 17 | 2 | 20 |
| 6½ | 4 | 3 | 1 | 9 |
| 6¾ | 1 | 4 | 1 | 3 |
| 7 | 1 | 2 | – | 2 |
| 7¼ | – | – | – | – |
| 7½ | – | – | – | – |
| 7¾ | – | – | – | 1 |
| Age in days | 165 | 126 | 134 | 156 |

It is the writer's opinion that the length-weight relationship may differ considerably with differences in feeding methods and that a comparison would be desirable. This can be done by the preparation of a length-weight conversion table for each species of bass at each bass farm, as illustrated by the following table:

LENGTH-WEIGHT CONVERSION TABLE FOR SMALLMOUTH BASS

| | STATE FISH FARM NO. 2 | | STATE FISH FARM NO. 5 | |
|---|---|---|---|---|
| Length (Inches) | No. Fish | Average Wt. (Oz.) | No. Fish | Average Wt. (Oz.) |
| 2⅜ | -- | ------ | 5 | .100 |
| 2½ | -- | ------ | 8 | .133 |
| 2⅝ | -- | ------ | 11 | .136 |
| 2¾ | -- | ------ | 20 | .160 |
| 2⅞ | 2 | .1875 | 32 | .176 |
| 3 | 11 | .2159 | 36 | .201 |
| 3⅛ | 19 | .2368 | 34 | .228 |
| 3¼ | 20 | .2750 | 22 | .273 |
| 3⅜ | 31 | .3042 | 18 | .285 |
| 3½ | 30 | .3458 | 16 | .352 |
| 3⅝ | 20 | .3927 | 21 | .393 |
| 3¾ | 19 | .4440 | 26 | .456 |
| 3⅞ | 16 | .4484 | 28 | .477 |
| 4 | 8 | .5000 | 31 | .524 |
| 4⅛ | 16 | .5475 | 25 | .580 |
| 4¼ | 5 | .6250 | 24 | .666 |
| 4⅜ | 12 | .6406 | 22 | .705 |
| 4½ | 29 | .6999 | 12 | .771 |
| 4⅝ | 15 | .7666 | 10 | .825 |
| 4¾ | 53 | .8844 | 10 | .875 |
| 4⅞ | 52 | .9639 | 8 | 1.000 |
| 5 | 54 | 1.0463 | 5 | 1.050 |
| 5⅛ | 45 | 1.1250 | 4 | 1.125 |
| 5¼ | 51 | 1.2230 | 3 | 1.250 |
| 5⅜ | 46 | 1.3289 | 4 | 1.375 |
| 5½ | 50 | 1.4675 | 1 | 1.750 |
| 5⅝ | 33 | 1.5417 | -- | ------ |
| 5¾ | 39 | 1.6346 | -- | ------ |
| 5⅞ | 32 | 1.7695 | -- | ------ |
| 6 | 19 | 1.7829 | -- | ------ |
| 6⅛ | 8 | 2.1094 | -- | ------ |
| 6¼ | 6 | 2.0622 | -- | ------ |
| 6⅜ | -- | ------ | -- | ------ |
| 6½ | 2 | 2.3750 | -- | ------ |
| 6⅝ | -- | ------ | -- | ------ |
| 6¾ | -- | ------ | -- | ------ |
| 6⅞ | -- | ------ | -- | ------ |
| 7 | 1 | 3.2500 | -- | ------ |

Survival percentage for the bass in any pond should be calculated from the number of fry needed to produce the resulting number of fingerlings. Since the greatest loss that occurs among young bass happens during the first two to four weeks when they are growing from one-half inch to an inch and one-half, if the survival percentage is determined from the fry the figure will invariably be less than when determined from the length of an inch and one-half. Also, it is essential that the numbers involved in determining survival percentages must be accurate. Estimates have practically no value.

## Summary

1. Suggestions are made for standard method of stating bass production in terms of quantity and quality of the fish produced.

2. For comparison of quantities of fish produced it is recommended that the mass weight of all fish produced in a pond having a known volume be obtained and these figures be transformed to show the mass weight of fish on the same basis per common unit of volume.

3. The common unit of volume of water suggested is one million gallons.

4. For comparison of lengths of bass produced it is suggested that measurements of length of a random sample of 150 fish be compiled to form a table of length-frequencies.

5. For comparison of length-weight relationships it is suggested that a length-weight conversion table be prepared for each species of bass at each place.

6. For comparison of size of bass, since size attained is a function of age, it is suggested that the age of the fish be determined from standard landmarks and always stated with statements of size.

7. A standard method of determining survival percentage is suggested.

# WHEN DO THE RAINBOW TROUT SPAWN?

H. P. K. Agersborg

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During the season 1932-1933, the State of New Hampshire had about 2,400 adult domesticated rainbow trout (*Salmo irideus, S. shasta,* and *S. gairdneri* and probably others and their hybrids) which were used as breeders. They varied in age from 3 to 13 years. In the past, the brood fish had been augmented by young fish, from year to year, when 2 years old; this was the reason for the difference in age amongst this lot of brood fish. The stripping had been done regularly in April. It was noted in the fall of 1932, however, that spawning commenced actually in the latter part of November and continued through the winter, spring and into the month of June. This was more or less in accord with known facts in reference to the spawning habits of these species. The lot of brood fish in question was probably all hybrids, which probably explains the unusually long spawning period.

In its native waters of the McCloud River, California, the rainbow (*S. irideus*) spawns during the months of February, March and April. It has been found to vary from this in different places where it has been introduced. Thus, at Wytheville, Virginia, the spawning season extends through November, December, January and into February, December and January being the best months. In Colorado, the period is from early May until July. Eggs of the steelhead trout (*S. gairdneri*) from Rogue River in Oregon and from certain streams in Washington have been shipped East. Fish resulting from these have been distributed in public waters under the name of rainbow or have been included in brood stock at the various hatcheries, Federal, State and commercial rainbow trout from the Klamath River in California, *e. g., S. irideus,* have been included with the rainbow (*S. shasta*) in plants of the East. All these three species have undoubtedly crossed with one another in various ways, hence these varieties of so-called rainbow trout in the eastern section of our country.

Hybridization amongst these species (including probably also *S. gilberti* and *S. newberri*) is evidenced by the extensive variation in color, shape, and in the number of large and small spots characterizing the individual. Some look like typical rainbow; some, like typical steelhead; some appear intermediate in many respects. It is not surprising, therefore, that the spawning season varies in the different localities to which trans-plants have been made.

Thus at Neosho, Mo., the spawning season usually begins about November 1, and extends to March 1; at Manchester, Iowa, it occurs between November 15 and March 15; in Montana, from April 15 to June 1; at Pittsford, Vermont, some spawn during November-December, and some during April-June, and in New Hampshire, as

we have seen, the spawning for the season 1932-1933 occurred from the last part of November to the middle of June.

For reasons we are unable to explain, the fish were not "gone over" until the first of March. Then it was found that about 600 had finished spawning; about 600 were in the act of spawning; about 600 were not "quite ready"; and circa 600 were regarded "barren." "We have always some 'barren' ones amongst the rainbow," it was explained to indicate the reason why so many were still sexually unripe. The keeping and feeding of so many "barren" fish amongst the brood fish is hardly consistent with economic pisciculture.

The "barren" fish were placed in a separate pool. During the last week of May and the first half of June, the "barren" rainbow, however, spawned, but the eggs were not saved for there was no room in the hatcheries.

The spawning of the "barren" fish proved conclusively that the range of spawning of the New Hampshire varieties of rainbow trout extends over a period of circa eight months—from the last of November to about the middle of June.

The so-called barren rainbow trout resembles the steelhead trout (*S. gairdneri*), much more so than did any of the others. The fall spawners looked more like the rainbows *S. irideus* and *S. shasta,* and the winter spawners resembled somewhat all three species. Most of the fall and winter spawners and some of the summer spawners were stocked in streams and ponds in the various sections of the State.

Three hundred and fifty of the best looking steelhead-like trout and fifty of the best looking fall spawners, including a large male which started spawning in November and continued to spawn as late as March, were saved and placed in a new pool created for this purpose.

The original rainbow pool was cleaned and 800 twelve-inch two-year-old so-called rainbow trout were placed in it. During the spring, summer and fall of 1933 they were fed mostly on an improved trout food, described elsewhere, and on whole salmon eggs. The steelhead trout were also fed on this food and so were the rainbow-like trout described. The two-year-old fish doubled in size during the stated period, and the older fish, which were of different sizes and ages, and kept in a separate pool, attained a much more uniform size.

By November 4, 1933, these two lots of fish were exceedingly attractive looking fish. They had been fed three times daily during the time stated above, and each time as much as they would eat. During this period, the younger of these two lots attained the same size as the largest of the older fish.

For obvious reasons it was thought best not to mix these two lots of brood fish. Because, when rearing animals of any species, it is of the utmost importance to know the racial make-up of the breeders. The fish in this instance were known to some extent; two-thirds were two and one-half years old, the descendants of the early spring spawners,

most of which had been stocked already in various rivers and ponds of the State. Most of the older of these fish, the remaining one-third of the entire lot, were steelhead-like rainbow at first designated as barren fish but which were found to be late spawners, and which varied in age from three and one-half to thirteen and one-half years. A few of the older fish were early spawners.

The difference in age and sexual ripeness of the two lots were regarded physiological differences of such a nature that should these two lots of fish be mixed there would be a "big fight" between the two tribes mostly due to differences in sexual odor between the two sexes of the two lots.

Furthermore, if fish of difference in age and sexual development are kept in separate pools it is easier to keep track of the offspring and of the adult fish as well.

Nevertheless, these two lots of fish, described above, were mixed. It was claimed that the fish could be identified when stripped.

Unfortunately, even if it were possible to tell accurately the age of the fish without reading the scale-rings (many of the younger fish looked much like the older steelhead trout, and probably were late spawners also) all the other points of advantage enumerated above were lost, having apparently no significance.

After the two lots of brood fish were mixed many died due to injury received from fighting, due to improper feeding, and due to a radical change in food qualitatively and quantitatively, explanation to the contrary notwithstanding, that the mortality amongst these brood fish was due to their being cared for too well during the spring, summer and fall prior to the time they were placed in a common pool.

# IOWA NURSERY POND KETTLE AND OUTLET

W. W. Aitken
*Iowa Fish and Game Commission*

In order that a simple, substantial, and efficient kettle and drain might be installed in the bass rearing ponds at Lake Wapello, the first of the 32 artificial lakes now under construction in Iowa, a careful survey and study was made of such equipment used in other parts of the state.

The type outlet which operated most efficiently was the elbow-type drain. In this type no expensive valves are needed, unhandy splash boards are eliminated, and total leakage is stopped. In addition the pond level maintenance is perfectly flexible, as the upright pipe can be turned down to sustain any depth.

However, the elbow-type drain and box-type kettle had certain disadvantages and the Iowa type was evolved to correct these discrepancies, yet maintain the fine features of the kettle and elbow outlet.

Square or rectangular boxes for kettles had certain shortcomings such as right angled corners with vertical walls, inadequate openings on the sides to meet the channel drains of the ponds, and susceptibility to frost action which destroyed the sides of the kettle in a few years.

The outlet elbow when threads become worn could not be backed off of the horizontal drain pipe and repaired unless a large depression was left in the kettle. This presented a concrete well that collected the fish in an undesirable place.

The accompanying sketch will show detailed construction of the Iowa Kettle and Outlet. Attention is particularly called to the sloping sides and rounded corners of the kettle. This facilitates hand-picking and difficult dipping of the small fish from inaccessible corners such as is experienced with kettles having angular corners and vertical walls. This construction also eliminates need for form lumber in the concrete work. The slanting walls of the kettle resist frost action because they exhibit the same effect as battered walls. Concrete structures of any kind that are adamant to freezing are very desirable.

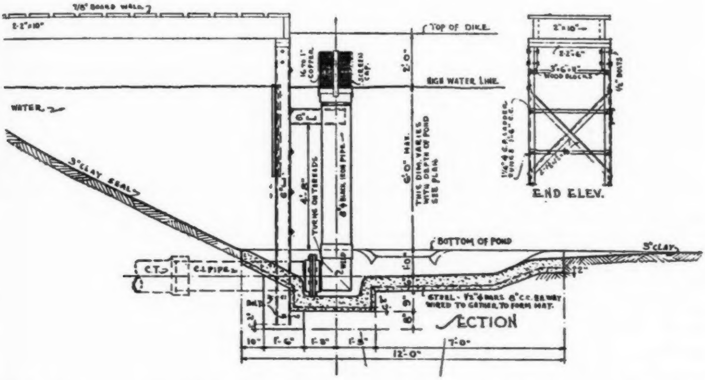
The outlet as shown by sketch illustrates the mechanics of the companion flange and welded elbow. By constant use, threads on black pipe wear out in eight to twelve years at points of articulation. When this occurs on the Iowa Outlet, the worn part will either be the outside companion flange, or the threads on the elbow. In either case the worn part can be easily replaced, or repaired.

These kettles and outlets are now in operation at Lake Wapello,

on ponds from one to two and one-half acres in area. Their cost is quite low. All the material needed is from three to four cubic yards of concrete at an average cost of $6.00 per cubic yard plus $2.00 per cubic yard for steel. The pipe ensemble, if eight inches, costs from $30.00 to $45.00. The entire cost of kettle and drain ranges in price from $55.00 to $75.00.

The Iowa Type Kettle and Outlet, combines low first cost, simplicity of construction, ease and efficiency in operation, and, most important of all, by eliminating those factors that give the fish culturist trouble, reduces mortality to a minimum.

Acknowledgment is gratefully made to J. C. Gillman, C. E., who suggested and approved some of the principles involved, and to Frank Ray, Architect, for his assistance in the detailed drawing.




New Method for Attaching Outlet Pipe, Iowa Nursery Pond Kettle designed by W. W. Aitken.

**EDITOR'S NOTE:** The U. S. Bureau of Fisheries has used the "elbow type" drain for many years. The only difference in the Bureau's outlet and the one described by the author is that Mr. Aitken attaches the elbow by means of a flange to the outlet pipe, whereas in the Bureau's type the elbow is screwed directly onto the outlet or drain pipe. The advantages are enumerated by the author above.

# A STUDY OF THE FOOD COST OF TROUT IN NEW YORK STATE HATCHERIES

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In the propagation of trout in a State producing millions of fish annually, the feeding costs assume very sizable proportions. The term "feeding costs" in itself means very little, because it is affected by conditions which vary with the locality, with the hatchery, and with the hatchery management. To make possible a systematic analysis of these underlying conditions, New York State in March of this year introduced into its trout hatcheries report forms, which will hereafter be referred to as the "Feeding Charts," upon which the hatchery men record daily the more important of these items.

The Feeding Chart used to date has proven satisfactory. Each period extends over 28 days, giving thirteen periods per year. The 28-day period was selected rather than a monthly one to avoid conflict with the other reports of the hatcheries, most of which must be submitted on the first of each month, and also to give equal periods for the comparison of growth rates and other data. Opposite each date on the chart is a space for the average noon water temperature—noon temperature being selected because that is nearest to the average "feeding temperature." Each sheet has columns for five lots. At the heading of these are spaces to record the species, the lot number and description—e.g. Browns Lot 1, Caledonia Strain, early spawned—and the date started or date of initial feeding. Lines are provided for recording each day the number and weight of fish shipped, the mortality, any disease treatment, and the pounds of food fed, for each lot. Directly under the spaces for daily records for each lot are lines for the number of fish per pound at the start, at the middle, and at the end of the period (Items 1-3). This means that the size of fish is determined and recorded each two weeks. This applies to fry and fingerlings only; yearlings, whose growth rate is less rapid, are weighed at the end of four week periods only; breeders are weighed at the end of twelve week periods. From Items 4-9, inclusive, can be found the gain in weight of the fish in the lot (the necessary steps are listed under "Calculation of Data" at the left). A total of the daily records of "Lbs. food fed" gives the amount of feed used during the period, and this divided by the gain in weight of the fish will give the "Lbs. of food per lb. of fish gained" (Item 12). From this and Item 11—Diet Composition and cost per lb.—the "Food cost per lb. of fish gained" is calculated. The record of the weight of fish per cubic foot of water is made at the end of each period.

The completed reports from each hatchery are condensed on a summary sheet for that purpose: on these sheets the amount of food fed in per cent of body weight daily and the per cent mortality for the period are also recorded for each lot. The data from each hatchery are then compared with the state average and criticized on that basis. A copy of this summary with the criticisms is then sent to the foreman of that particular hatchery.

Finally, the data from each hatchery are incorporated into a "State Summary." This is made up of two parts; the first a record of the number and weight of fish shipped during the period from each hatchery, the number and weight of fish on hand at the end of the period, and the total pounds of food used at each hatchery and its cost; the second part is a table made up from the data taken from the various individual hatchery summaries. A table of the average values for all the lots in each hatchery is also made. Copies of the complete "State Summary" are sent to each hatchery foreman, enabling him to compare his practices and results with those of each of the others.

The table of summarized data (Fig. 1) is taken from the Feeding Charts from February 27th to August 13th, representing six twenty-eight day periods. It was unfortunate that the charts were not used in all the hatcheries a little earlier in the year so that sufficient data could have been obtained on one-inch fish for publication. And since on August 13th few stations had trout averaging over three inches in length, except brook trout for which we have figures up to five inches, a complete report on all size groups can not be given at this time. A study of the table will also show wide variation between the maximum and minimum values. It is certainly true that after another year's study we will be able to arrive at truer averages. However, the different conditions in the various stations explains much of the variation; for example the wide range of values for "Amt. food fed in per cent body weight daily" is partly due to the difference in water temperatures. The number of fish for which we have records of course varies from day to day due to shipments, but on June 18th, for example, we had over nine and one-half million fish on record. The averages for such a number of fish should give at least a close approximation to the real average values.

A few general trends of the table will be pointed out. As the season adances the temperature of course gradually increases. The average value for "Amt. food fed in per cent body weight daily" decreases as the fish become larger. Better conversion obtains, with a resulting cheaper cost of production. Although we do not have sufficient data on yearlings to feel that we can give any averages on the publication, the data at hand indicates that this downward trend in the food cost of production does not continue

FIGURE 1. SHOWING SUMMARIZED DATA FROM HATCHERY FEEDING CHARTS

| Species | | Brook Trout | | | | Brown Trout | | Rainbow Trout | | Lake Trout | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Size (Inches) | | 2 | 3 | 4 | 5 | 2 | 3 | 2 | 3 | 2 | 3 |
| Average noon water temperature | Average | 49 | 52 | 54 | 54 | 52 | 55 | 52 | 56 | 53 | 54 |
| | Minimum | 44 | 47 | 49 | 53 | 48 | 51 | 47 | 54 | 46 | 47 |
| | Maximum | 54 | 61 | 59 | 55 | 58 | 59 | 61 | 58 | 61 | 58 |
| Amount food fed in % body wt. daily | Average | 12.3 | 9.3 | 8.0 | 6.5 | 9.0 | 7.0 | 11.8 | 7.7 | 10.6 | 8.8 |
| | Minimum | 5.9 | 5.7 | 4.6 | 5.4 | 6.2 | 4.8 | 8.1 | 6.8 | 6.5 | 5.7 |
| | Maximum | 17.1 | 11.9 | 13.5 | 7.2 | 14.5 | 10.8 | 14.1 | 8.1 | 16.0 | 13.0 |
| *Lbs. food to produce a pound of fish | Average | 4.8 | 3.5 | 3.0 | 2.6 | 4.6 | 4.0 | 5.8 | 3.4 | 5.4 | 3.6 |
| | Minimum | 2.9 | 1.8 | 2.1 | 2.1 | 3.0 | 3.1 | 2.9 | 1.9 | 3.4 | 2.5 |
| | Maximum | 6.4 | 5.4 | 4.8 | 3.4 | 7.2 | 5.9 | 9.2 | 4.6 | 7.0 | 4.2 |
| Food cost to produce a pound of fish | Average | .27 | .20 | .16 | .13 | .27 | .21 | .32 | .18 | .30 | .18 |
| | Minimum | .20 | .10 | .11 | .12 | .16 | .12 | .17 | .07 | .19 | .15 |
| | Maximum | .40 | .29 | .26 | .14 | .41 | .28 | .55 | .24 | .48 | .21 |
| **Food cost to produce 1,000 fish | Average | .76 | 1.60 | 2.43 | 3.81 | .76 | 1.68 | .90 | 1.44 | .57 | 1.17 |
| | Minimum | .56 | .80 | 1.67 | 3.52 | .45 | .96 | .48 | .56 | .36 | .98 |
| | Maximum | 1.12 | 2.32 | 3.95 | 4.10 | 1.15 | 2.24 | 1.54 | 1.92 | .91 | 1.37 |
| ***Lbs. fish per cu. ft. water | Average | 1.4 | 2.2 | 3.2 | 5.5 | 1.6 | 3.6 | 1.4 | 3.9 | 1.3 | 3.2 |
| | Minimum | 1.0 | 1.4 | 1.4 | 3.3 | 2.9 | 2.0 | 1.8 | 1.2 | 1.7 | 1.5 |
| | Maximum | 2.2 | 3.4 | 4.8 | 7.8 | 2.7 | 5.5 | 2.1 | 5.7 | 2.0 | 4.9 |
| Per cent mortality for 28-day periods | Average | 1.4 | .6 | .3 | .3 | 1.3 | 2.9 | 3.1 | 1.1 | 1.7 | 1.5 |
| | Minimum | .1 | .06 | .05 | .01 | .2 | .2 | 1.7 | .2 | .7 | .2 |
| | Maximum | 3.4 | 1.3 | .8 | .5 | 2.8 | 17.8 | 6.0 | 3.1 | 2.9 | 6.2 |

*Lbs. food to produce a lb. of fish (conversion) given on a wet basis.
**Value given is for the raising of that size fish from the next smaller inch fish—three-inch from two-inch, etc.
***Weight of fish per cubic foot of water given for fish in troughs only.

indefinitely. By totaling the figures given for the respective size groups of any species, one may arrive at the total food cost to produce 1,000 fish. Our cost figures are mostly based on diets of one or more of the following ingredients: beef liver, beef hearts, hog melts, sheep plucks, clam heads, and buttermilk (dried). The cost per pound of the feed is about six cents. On that basis and neglecting the cost to produce one-inch fish, which will obviously be very small, the average food cost to produce 1,000 five-inch brook trout in New York State hatcheries to date this year is $8.60.

In addition to the data outlined in the table above, much information may be obtained from the use of these Feeding Charts of value only to the foreman of the particular hatchery. For example, the growth of a lot of fish in one pond compared with that in another along with the known amounts of food fed to the respective lots, indicates to the foreman what his feeding trend should be. Where different feeding methods are employed or different diets are used, the results show up very plainly.

By the extension of this study over a longer period, we hope to obtain information bearing on such points as the reason for the superiority of one station in growth rate and economy of production of fish from the same source; the comparison of different strains of fish in these factors; the food cost of holding breeders and therefore the food cost of egg production; and especially the actual food cost of production of all sizes of the different species of fish and the amount to feed to get the best results and cheapest production.

In conclusion, the author wishes to express his appreciation to Mr. A. V. Tunison, Senior Laboratory Technician in Aquatic Biology, located at the Cortland Experimental Hatchery, who was the originator of the Feeding Charts and who has given invaluable assistance and advice throughout this study.

## Discussion

Dr. Davis: Are you using the same diet for each of these species, or a different diet?

Mr. Deuel: In general, yes, because one hatchery ordinarily uses the same diet for all species they have in that hatchery. Different hatcheries do use different diets.

Dr. Davis: These figures are based on experience at one hatchery?

Mr. Deuel: No, a compilation of all the averages from each hatchery. There are fourteen hatcheries, and these are average figures.

Dr. Davis: Then you are making a comparison of the rearing of brook trout with rainbow trout or brown trout, and you are not necessarily comparing similar diets.

# RECENT INFESTATIONS OF GOLDFISH AND CARP BY THE "ANCHOR PARASITE," *LERNAEA CARASSII*[1]

WILBUR M. TIDD

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Since 1929 several goldfish breeders in Ohio have been troubled with a crustacean parasite which embeds itself in the flesh of their goldfish, causing unsightly lesions and tumor-like growths. This parasite belongs to the Entomostraca, a group containing also the copepods and daphnia which serve as food for the young of our game and commercial fishes. It was described and named *Lernaea carassii* (1933) by the author. The common name of "anchor parasite" is applicable to this form due to the presence of two pairs of horns or arms which grow out from the anterior end of the body and anchor it firmly in the flesh of the host. Attached to the anchor portion is the elongated body of the parasite resembling a piece of string hanging from the fish. Often the parasites become covered with algae or protozoa which make them very conspicuous.

The "anchor parasite," *Lernaea carassii,* differs markedly in its structure and habits from other North American species of the Genus Lernaea. It resembles a Japanese species, *Lernaea elegans,* reported by N. Nakai and F. Kokai (1931) as being a menace to goldfish, carp and eels in Japan. If *Lernaea carassii* were a species native to the United States it seems strange that it could have so long escaped the attention of fanciers of ornamental fish and fisheries biologists. This parasite is not specific for the goldfish alone, as nine other species have recently been shown to carry it, but so far as I know there are no published records of its occurrence upon species other than goldfish. If it is a native parasite why should its occurrence have been restricted to a fish which has been introduced into the United States and propagated under artificial conditions? While I am unable to cite records to show that this parasite has been recently introduced upon shipments of goldfish or tropicals, nevertheless the evidence seems to justify this viewpoint.

Enders and Rifenburgh (1928) reported an infestation by Lernaea upon goldfish in Indiana. In the fall of 1933 I received, from a large goldfish farm in Indiana, several goldfish carrying "anchor parasites." While at present I have records for the occurrence of the "anchor parasite" in Ohio and Indiana only, I would not be surprised to find that it already has a wide distribution range. Several millions of goldfish are produced in the United States each year and sold, for retail trade, to pet shops and chain stores in various

[1]The photographs which accompany this article are published by permission of the Ohio Commissioner of Conservation.

parts of the country; besides goldfish breeders improve or enlarge their stock by purchases from their competitors. With the present methods of transportation highly developed, shipments of fish may be made from such widely separated points as New Jersey and Missouri. Thus the chances of the "anchor parasite" becoming widely distributed in a relatively short period of time seem excellent.

In the early part of August of this year Mr. C. J. Riley of Port Clinton, Ohio, reported heavy losses of carp by the owner of a carp pond near that place. This pond is situated about thirteen miles southwest of Port Clinton, in the fork formed by the junction of Little and Big Mud Creeks, which in turn empty into the west end of Sandusky Bay through Mud Bay. In the latter part of April and early May thirty tons of carp, two tons of goldfish, and a few dogfish were seined from Mud Bay and placed in the carp pond. This pond is 705 feet long and 180 feet wide with an average depth of 3.5 feet. Water is pumped in at the rate of 1,100 gallons per minute from a channel opening into Little Mud Creek. Eight flumes form the outlet and drain into an open ditch opposite the inlet. This ditch empties the water into a marshy area drained by Little Mud Creek.

In the early part of July the goldfish died and were thrown over the bank of the pond upon marshy ground. It was then noticed that the carp in the pond were showing signs of distress. Many were jumping clear of the water and swimming about at the surface. The pump was started and permitted to run continuously in an effort to correct this condition, but more carp showed signs of distress and soon the mortality became high. The owner reported a loss of eighteen tons of carp over a period of two weeks' time.

When the pond was first visited on the 23rd of August I found the fish to be heavily infested with "anchor parasites." This was the worst infestation that I have ever seen by animal parasites. The sight of the skeletons and decaying fish which had been thrown over the sides of the pond was appalling. By this time the mortality rate had decreased to approximately one hundred pounds of carp per day. Forty-two dead carp were seen floating about the edges of the pond. All of these which were still firm enough to permit examination as well as those which had been recently thrown over the banks of the pond were heavily infested with "anchor parasites." Seven live carp and a dogfish (or bowfin) were captured and all found to be heavily parasitised. All the parasites from two of these carp were removed and counted. From the larger, measuring 520 mm. (19.76 inches) we removed 1,426 "anchor parasites." This number does not include those inside the mouth as the head was saved for demonstration purposes. From the other fish which measured 332 mm. (13.07 inches) 458 parasites were collected. All the live carp examined appeared to be in a very poor condition, the fins were covered with lesions made by the parasites, and by pressure it was possible to extrude pus from lesions on some of the fish. Examination of the scales

under which many of the parasites were embedded revealed a distinct scale injury. Five of the live fish and one which had recently died were opened and the viscera examined by Dr. R. V. Bangham and the author, and as far as could be ascertained they were found to be free of worm or protozoan parasites. The viscera showed numerous adhesions and were practically devoid of fat.

On August 25th the following catch was made upon the seining grounds in Mud Bay from which the carp pond was stocked: fifty-three small carp of which ten were parasitised with "anchor parasites"; four blue gills, three of which carried this parasite; and six gizzard shad which were free from "anchor parasites" or lesions. Since these small carp from the seining grounds were found to be parasitised, this suggests the possibility that "anchor parasites" were introduced into the pond with the large carp which were already parasitised in April and May when they were seined from Mud Bay.

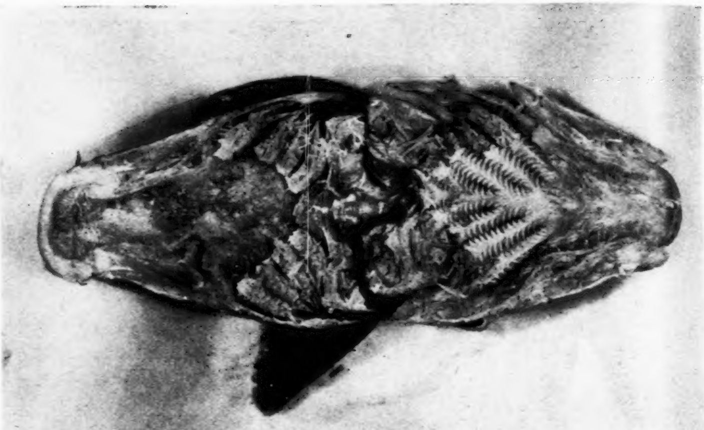
This infestation was much more severe than any yet encountered at the goldfish farms. The exact reason for this difference has not yet been ascertained, but a few factors are here suggested which may have been involved: (1) crowding into a small area of shallow warm water many large fish which may have been parasitised when the pond was stocked in the spring; (2) pumping into the pond water containing young females of this parasite. These came either from infested fish in the waters of the inlet or from the carp in the pond itself, as young females were found to be present in considerable numbers in water escaping from the outlet. It seems quite possible that this water may have circulated by a roundabout route to the inlet; (3) the extreme shallowness of the water together with a very warm dry summer which was probably favorable to short incubation periods between broods of this parasite.

If the "anchor parasite" were specific for only goldfish and carp it might cause little or no concern to those interested in the propagation of game fishes, but unfortunately this is not the case. The host record at present includes one commercial fish of Lake Erie, a common minnow of our inland streams, two tropical fishes, game fishes, and frog tadpoles. The following are records of the hosts and localities where the "anchor parasite" Lernaea carassii has been found:

| *Host* | *Locality* |
|---|---|
| 1. Goldfish, *Carassius auratus.* | From goldfish at Cincinnati, O., July 24, 1930. From goldfish at Chicago, Ill., by Mary Talbot, July 19, 1933. From goldfish farm in Indiana, Oct. 21, 1933. From Nielson's seining grounds, Sandusky Bay, Aug. 27, 1934. |
| 2. Carp, *Cyprinus carpio.* | Experimental infestation of European and mirror carp, April 24, 1934. From carp pond near Port Clinton, O. Aug. 23, 1934. |

1. Microphotograph of the "anchor parasite," Lernaea carassii, taken through a binocular microscope.

2. Photograph of a small goldfish experimentally infested with "anchor parasites."



3. Photograph of "anchor parasites" on the floor and roof of the mouth of a carp. Note that most of the parasites have attached themselves in the depressions on these surfaces.

4. Photograph of the tail of a carp infested with "anchor parasites." Note the coalescing lesions and parasites in clumps.

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| | |
|---|---|
| 3. Dogfish, *Amia calva.* | From carp pond near Port Clinton, O., by C. J. Riley, Aug. 24, 1934. |
| 4. Common Shiner, *Notropis cornutus.* | Experimental infestation, May 27, 1934. |
| 5. Blunt-nosed minnow, *Hyborhynchus notatus.* | Experimental infestation, May 20, 1934. |
| 6. Guppy fish, *Labistes reticulatus.* | Experimental infestation, April 19, 1934. |
| 7. Paradise fish, *Macropodus opercularis.* | Experimental infestation, March 10, 1934. |
| 8. Silver cat, *Ictalurus punctatus.* | From Nielson's seining grounds, Sandusky Bay, by Mark Shellhaas. Aug. 27, 1934. |
| 9. Blue Gill, *Helioperca incisor.* | From Put-in-Bay, O., by E. N. Warner, July 27, 1934. From East Harbor, by C. J. Riley, Aug. 27, 1934. |
| 10. Pumpkin Seed Sunfish, *Eupomotis gibbosus.* | From East Harbor, Aug. 27, 1934. |
| 11. Frog tadpoles, *Rana species?* | Experimental infestation, Oct. 21, 1933. |

To date positive infestations have been obtained in every case where fish hosts were used in our experiments as cited above. It is impossible to say how extensive future investigations may prove the host lists of this parasite to be; likewise we have no data to show the parasitic load accommodated by hosts other than goldfish and carp. At the present time experiments are being conducted by T. H. Langlois and the author with eight species of game fish in an attempt to determine if they may be parasitised by the "anchor parasite."

We still have considerable detail of the life history of *Lernaea carassii* to work out and while the author does not wish to issue prematurely the results of unfinished experiments, still there are a few facts about the life history, which if presented here may be helpful to those interested in preventing the spread of the parasite: (1) the "anchor parasite" has a direct life history, no intermediate host being necessary; (2) the larvae emerge from the egg strings of the parent as free swimming forms, and in this stage they may be transported by running water; (3) there is a second free swimming stage possessed by the females after they have completed a part of their development on the gill filaments of their host. This stage may also be transported by running water; (4) young females may pass the entire parasitic phase of their life history upon one host or they may leave the gills and parasitise another fish of the same or of a different species.

Since we possess so little information concerning this form it would be well that those interested in the propagation of game fishes consider the "anchor parasite" a potential menace to their fish and

take necessary steps to prevent waters containing infested goldfish or carp from reaching their ponds.

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1933. A New Species of Lernaea (Parasitic Copepoda) from the Goldfish. The Ohio Journal of Science. Vol. 38, pp. 465-469.

## Discussion

The President: Another paper along the same line, prepared by Mr. Wilbur M. Tidd and entitled "Recent Infestations of Goldfish and Carp by the 'Anchor' Parasite," *Lernaea carassii,* will be presented by Mr. Langlois of Ohio.

Dr. Detweiler: I would like to ask the speaker if the anchor filament in the Lernaea develops in the same way as it does in the Salmincola edwardsii. If I mistake not, the second maxilla grasps the anchor filament and then becomes permanently fused with it.

Mr. Langlois: That is the way it is essentially developed.

# NOCTURNAL DEPRESSIONS IN THE DISSOLVED OXYGEN IN FISH PONDS WITH SPECIAL REFERENCE TO AN EXCESS OF COARSE VEGETATION AND OF FERTILIZERS (TEXAS)

A. H. Wiebe

*Texas Game, Fish and Oyster Commission*

## Introduction

The value of the larger types of aquatic plants in fish ponds has been a subject for discussion at these meetings for a number of years. The belief was somehow current that the coarse vegetation was necessary for the successful operation of fish ponds. Among the virtues ascribed to an abundant growth of vegetation, the following were prominent: shelter, shade, increased food production, and oxygenation of the water. On several occasions the writer has met fish-cultural officials from various states who were frantic because they had no coarse vegetation in their fish ponds. Usually they ascribed their poor production to the absence of vegetation. In recent years, however, a marked change of opinion as to the value of coarse vegetation has occurred. And although there still are some people who are worrying over the problem of increasing the growth of vegetation; the best fish-cultural opinion of the country is now concerned with the control of vegetation rather than with promoting its growth. The writer has found that with the proper technique fish can be grown successfully in the total absence of all forms of vegetation.

In 1928, in his report as vice-president for aquatic biology and physics, Dr. Embody writes in part as follows: "The writer must confess a radical change of opinion in regard to the value of coarse vegetation in the rearing ponds since he has been experimenting in ponds destitute of such plants . . . . The higher plants including the pond weeds, water weeds, cattails, waterlilies and the like, cannot be considered anything but weeds . . . . Hence the last step to be taken in connection with successful pond fertilization is to eliminate higher plants entirely if possible; but if not so, at least keep them in check by frequent cutting."

It is not the writer's intention to discuss the general economy of coarse plants. For such a statement the reader is referred to the article just mentioned. The writer is concerned primarily with a partial answer to a question raised at our Columbus (Ohio) meeting, namely: What effect does an abundance of coarse vegetation have on the oxygen supply during the night? Also, is it possible

that the addition of organic fertilizers may depress the dissolved oxygen to the danger point? In the discussion that developed on this point last year the writer maintained that as long as the vegetation was alive, the effect on the oxygen during the night could be disregarded. The answer given here is very incomplete because we in Texas do not yet have any experimental figures to show what the oxygen requirements of the various species of fish are under varying conditions of temperature and reaction of the water. Unfortunately, too, there were no ponds available that could have been used as controls. We can, therefore, only state what happened to the dissolved oxygen during the night in certain ponds that have an abundance of coarse vegetation: *Chara, Naies, Potamogeton, Phylotria,* etc., and trust that these data have some significance.

The following points should be kept clearly in mind while examining the data presented in this paper:

(1) During the hours of daylight plants produce more oxygen than they consume; hence the $O_2$ increases during the day.

(2) During the hours of daylight plants consume more $CO_2$ than they produce, hence the water becomes more alkaline; i. e., the pH goes up.

(3) During the night processes (1) and (2) are reversed.

(4) Bacterial activities are inhibited by strong sunlight, hence bacterial activities are at a maximum during the night and on sunless days.

## Depletion of Dissolved Oxygen During the Night in Ponds Heavily Infested with Coarse Vegetation or with Algae

In Figure 1 there are represented some graphs showing the dissolved oxygen and per cent saturation for a series of 9 ponds at the Huntsville (Texas) Hatchery at 2:00 P. M., June 6th, and at 5:30 A. M., June 7th; also for another series of 5 ponds at 5:00 P. M., July 30th, and at 5:30 A. M., July 31st. Some of the ponds occur in either series. The samples were taken among the vegetation about three inches below the tops of the latter. In most instances there were only a few inches of water over the tops of the plants. All ponds, except 26 and 27 were completely covered with coarse vegetation of the pond weed type. Pond 26 contained mostly cattails and grasses, and 27 had a waterbloom composed almost exclusively of the bluegreen algae, *Anabaena*. The temperature range at 2:00 P. M., June 6th, was from 88°-95° F. and at 5:30 A. M., June 7th, from 83°-85° F. The July 30th temperature ranged from 89°-92° F., and the July 31st temperature ranged from 82°-83° F. The pH in all ponds in both series was above 8.4 in the early morning as well as during the afternoon. Figure 1 shows that in the first series the dissolved oxygen at 2:00 P. M. ranged from 10.2-15.7 p.p.m. and the per cent saturation from 139-220 per cent; the next morn-

ing at 5:30 the dissolved oxygen in the same series ranged from 4.8-8.3 p.p.m. and the per cent saturation from 62-107 per cent. The graph shows further that the pond that had the lowest $O_2$ at 2:00 P. M., and hence the lowest per cent saturation, did not give the lowest values for these factors at 5:30 A. M. The pond that gave the highest values at 2:00 P. M. was second highest at 5:30 A. M.

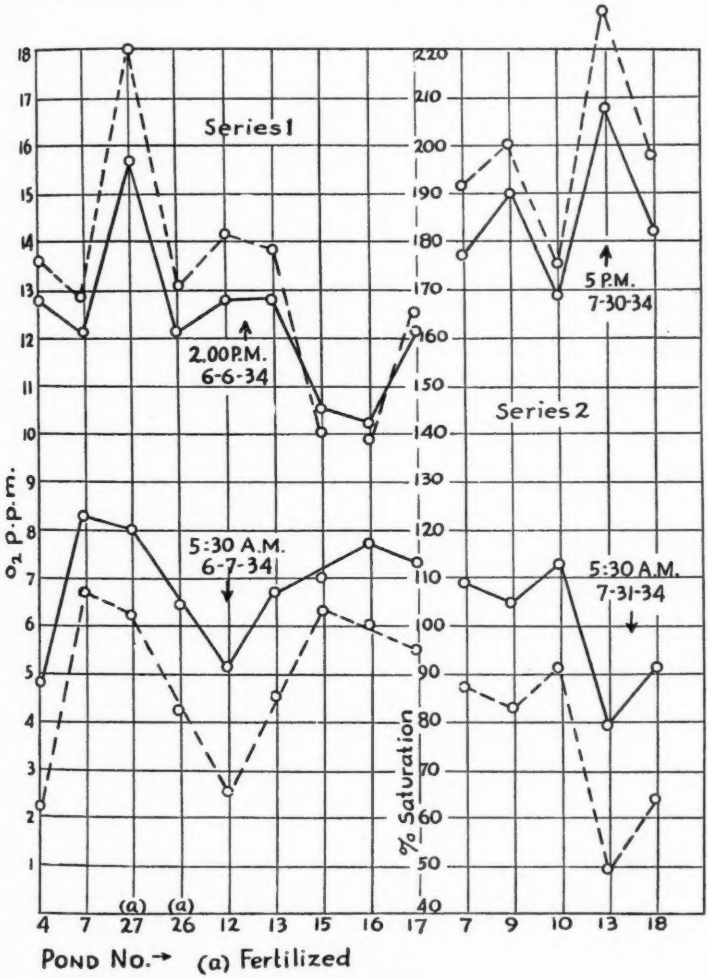


FIGURE 1

The graphs in series 2 (Figure 1) are interesting in that they show that the ponds that had the highest $O_2$ content and the highest per cent saturation 16.8 p.p.m. and 230 per cent, respectively, at 2:00 P. M., had the lowest $O_2$ content at 5:30 A. M., namely, 3.9 p.p.m. and 49 per cent.

These graphs in Figure 1 suggest that the vegetation may exert a

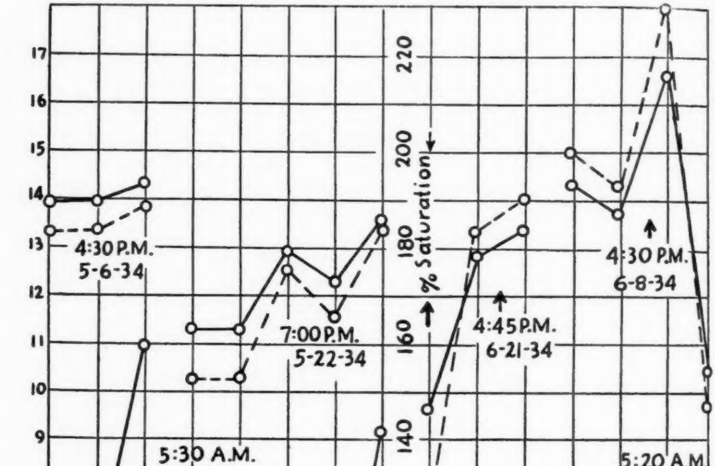


FIGURE 2

marked effect upon the dissolved oxygen during the night. It is impossible to estimate quantitatively the amount of live and dead vegetation in a pond. We also have not estimated the amount of oxygen consumed by the fish or of the amount passing into the atmosphere. However, the assumption seems warranted that, (1) the difference, in $O_2$ for the different ponds in the afternoon samples are associated with differences in the amount of live vegetation in the ponds; and (2) that the variations in the $O_2$ reduction during the night are associated with different quantities of dead vegetation. In some instances such differences were apparent to the eye.

Figure 2 gives additional proof of the material reduction in the dissolved oxygen during the night and shows saturation values of 50 per cent or slightly less in samples taken early in the morning. The temperature ranges for the data in Figure 2 are about the same as those given above for Figure 1. Space does not permit a detailed analysis of Figure 2 but attention should be directed to the low values for $O_2$ in ponds Nos. 4 and 12 at 5:30 A. M. on May 7th. It should also be noted that pond C, which served as a control and had no vegetation in it, showed the least reduction in $O_2$ during the night of the four ponds sampled on that date. This pond had the lowest $O_2$ in this group at 5:00 P. M. but the second highest at 5:30 A. M.

Figure 3 shows variations in the reduction of dissolved oxygen and per cent saturation in ponds Nos. 19 and 4 at different times during the summer. The graphs show that there is no marked variation in the concentration of dissolved oxygen during the late afternoon as the season progresses. Such variations as occur are, at least in part, due to the fact that the samples were not always taken at the same hour, and to variations in the amount of available solar energy. There is, however, a very marked and steady decline in the concentration of $O_2$ and hence in the per cent of saturation in the early morning samples. Of special interest are the values given for pond No. 19 on July 31st. At 5:00 P. M., July 30th, the $O_2$ was at a maximum for the season, at least in so far as samples had been taken. The $O_2$ at 5:00 P. M. amounted to 14.0 p.p.m. with a saturation value of 200 per cent. At 5:30 the next morning the $O_2$ was down to 0.8 p.p.m. and the per cent saturation was only 11 per cent. These values for July 30th and 31st were obtained after No. 19 had been treated with sodium arsenite. These values for July 31st are indicative of what might happen if the plants die during hot weather.

The values for ponds Nos. 19 and 4, with the exception of the last values for No. 19 (July 30-31st) are directly comparable and both series of values show the effect of dead vegetation which accumulates as the season advances.

In Figure 4 are shown variations in the dissolved oxygen, per cent saturation, and free $CO_2$ deficiency (same as phynolphthalein

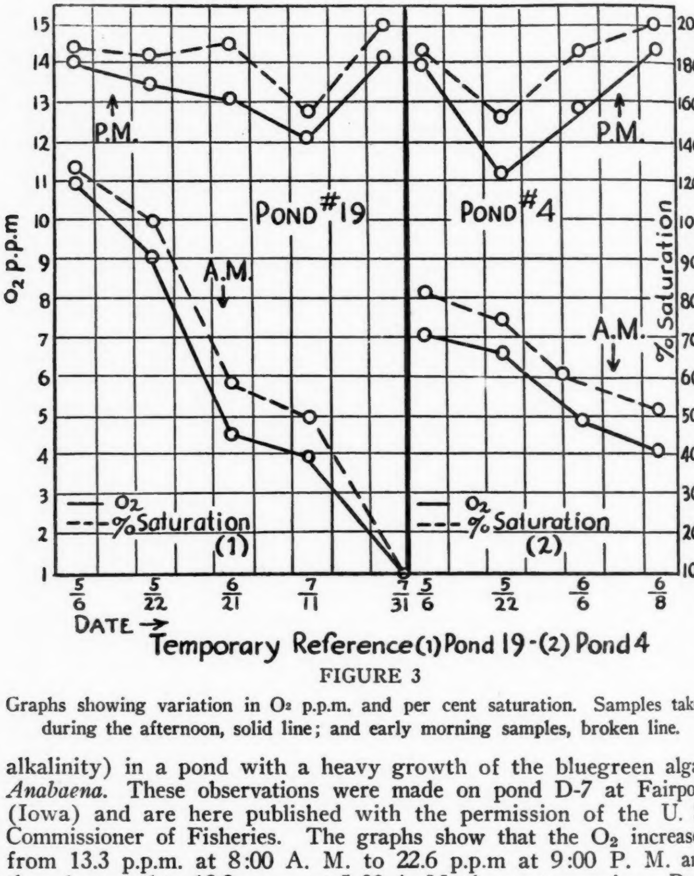


FIGURE 3

Graphs showing variation in $O_2$ p.p.m. and per cent saturation. Samples taken during the afternoon, solid line; and early morning samples, broken line.

alkalinity) in a pond with a heavy growth of the bluegreen algae *Anabaena*. These observations were made on pond D-7 at Fairport (Iowa) and are here published with the permission of the U. S. Commissioner of Fisheries. The graphs show that the $O_2$ increased from 13.3 p.p.m. at 8:00 A. M. to 22.6 p.p.m at 9:00 P. M. and then decreased to 12.2 p.p.m. at 5:00 A. M. the next morning. During the same time the per cent saturation rose from 163 per cent to 305 per cent and then decreased to 152 per cent. The free $CO_2$ deficiency rose from 46 p.p.m. at 8:00 A. M. to 75 p.p.m. at 5:00 P. M. and then declined to 52 p.p.m. at 5:00 A. M. These determinations were made on surface samples, but since this alga remains near the surface throughout the day and night, these results show that as long as these plants remain alive, there is no danger that the oxygen will be reduced to the danger point during the night. Results similar to the above have been obtained by the

writer with green algae in aquaria and in glass carboys both at Fairport (Iowa) and at Huntsville (Texas).

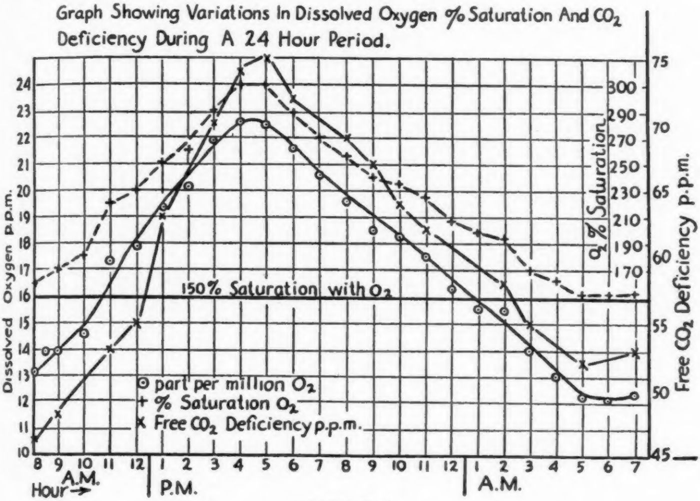


FIGURE 4

In a similar report by Dr. Prescott (reported in Collecting Net for 1933) it is stated that in Storm Lake (Iowa) fish were dying in large numbers after bluegreen algae had reached the water-bloom stage. In experimental aquariums fish died in this lake water even when there was an ample amount of $O_2$ to sustain life. Dr. Prescott ascribes the dying of fish to the presence of hydroxyl amine, a decomposition product of bluegreen algae and presumably very toxic to fish. The presence in the lake water of hydroxyl amine was demonstrated qualitatively. Here is a very interesting problem for some one that has the proper mental and physical equipment to pursue it quantitatively.

## The Effect of Fertilizer on the Dissolved Oxygen

That the addition of the normal amounts of such fertilizers as superphosphate and cottonseed meal does not necessarily aggravate the situation, as far as dissolved oxygen is concerned, is shown by the $O_2$ values given for ponds 18, 19, 26 and 27 in Figures 1 and 2. On several occasions, as the graphs show, the $O_2$ values early in the morning for these fertilized ponds were higher than those for several of the unfertilized ponds.

A series of experiments performed in small concrete ponds also showed that the addition of fertilizer does not reduce the dissolved

oxygen to the danger point. Cottonseed meal was added to three concrete ponds (20'x3'x20") at the rate of 200, 400 and 800 lbs. per acre. The requisite amount of fertilizer was added in three portions as follows: 0.3 of total amount on July 7th, another 0.3 of total amount on July 17th and the remaining 0.4 on July 27th. Dissolved oxygen, pH, $CO_2$ and temperatures were taken on the water of these ponds at certain times. The results for the pond receiving the largest dose of fertilizer are shown in Table 1. All the values in Table 1 are for bottom samples. The table shows that the lowest $O_2$ value was 5.6 p.p.m. and that free $CO_2$ occurred rarely and then in small quantities.

TABLE 1. SHOWS DISSOLVED OXYGEN, pH, FREE $CO_2$ AND TEMPERATURE FOR FERTILIZER EXPERIMENT

| 1934 Date | Hour | $O_2$ p.p.m. | pH | $CO_2$ p.p.m. | Temperature |
|---|---|---|---|---|---|
| 7/ 7 | 4.00 P.M. | 10.0 | 8.4 | —6.0 | 88°F |
| 7/ 8 | 7.00 A.M. | 6.5 | 8.1 | 1.0 | 86° |
| 7/ 8 | 5.00 P.M. | 9.0 | 8.3 | —4.0 | 92° |
| 7/ 9 | 7.00 A.M. | 5.6 | 8.1 | 3.0 | 86° |
| 7/ 9 | 5.00 P.M. | 9.0 | 8.3 | —4.0 | 92° |
| 7/10 | 7.00 A.M. | 6.7 | 8.1 | 3.0 | 86° |
| 7/10 | 5.00 P.M. | 12.0 | 8.4 | —8.0 | 90° |
| 7/11 | 7.00 A.M. | 7.2 | 8.2 | 0.0 | 82° |
| 7/11 | 5.00 P.M. | 14.4 | 8.5 | —10.0 | 91° |
| 7/12 | 7.00 A.M. | 8.5 | 8.3 | ——— | 81° |
| 7/16 | 6.00 P.M. | 11.2 | 9.2 | —22.0 | 90° |
| 7/17 | 5.00 A.M. | 6.65 | 9.1 | —14.0 | 84° |
| 7/17 | 6.00 P.M. | 12.0 | 9.15 | —20.0 | 90° |
| 7/18 | 6.00 A.M. | 6.1 | 8.95 | ——— | 83° |
| 7/18 | 5.30 P.M. | 12.8 | 9.15 | —19.0 | 90° |
| 7/19 | 6.00 A.M. | 5.6 | 8.85 | ——— | 85° |
| 7/19 | 5.00 P.M. | 13.6 | 9.3 | —23.0 | 91° |
| 7/20 | 8.00 A.M. | 6.9 | 9.0 | ——— | 85° |
| 7/26 | 6.00 P.M. | 16.0 | 9.6+ | —45.0 | 89° |
| 7/27 | 5.45 A.M. | 10.8 | 9.6 | ——— | 84° |
| 7/27 | 5.00 P.M. | 15.6 | 9.6+ | ——— | 90° |
| 7/28 | 6.00 A.M. | 7.2 | 9.5 | ——— | 83° |
| 7/28 | 5.30 P.M. | 13.8 | 9.6 | ——— | 88° |
| 7/29 | 5.00 A.M. | 6.6 | 9.5 | ——— | 83° |
| 7/30 | 6.00 P.M. | 14.2 | 9.6+ | ——— | 90° |
| 7/31 | 4.30 A.M. | 8.17 | 9.6+ | ——— | 81° |

Fertilizer was added to the pond on July 7th, 17th, and 27th.

## Conclusion

(1) As long as either the coarse vegetation or the algae are alive there is no danger of depleting the dissolved oxygen during the night.

(2) As dead and decaying vegetation accumulates in a pond there exists a strong possibility that the dissolved oxygen may be reduced to the danger point during warm nights and possibly also on murky days.

(3) There is little danger that the addition of reasonable amounts of fertilizer to fish ponds will cause any damage by reducing the dissolved oxygen.

(4) As a rule in ponds with an abundant growth of either coarse vegetation or of algae the water remains highly alkaline throughout the night (exceptions where muck has accumulated on the bottom).

(5) While the above conclusions apply in general, beware of the exception, for it is the exceptional happening that causes trouble. A series of cloudy, murky, hot days or nights may create conditions that would never occur on sunny days and cool nights. Remember nature does not subscribe to the Transactions.

# SOME CHEMICAL CHARACTERISTICS OF ADIRONDACK LAKES AND PONDS

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*Scope:* During the past five years, 1929-1933, a total of over 500 lakes and ponds has been studied by the chemistry unit of the New York State Biological Survey. These fall within the five major watersheds of the northern New York or Adirondack area:—The Champlain, the St. Lawrence (including the Grass, St. Regis, Salmon and Chateaugay systems), the Oswegatchie and Black River systems (including also the lesser tributary systems of the upper St. Lawrence and of northeastern Lake Ontario), the Upper Hudson and the Raquette.

The chemistry of these waters was studied with portable equipment during the period June 15-September 15 only. For large lakes and ponds, the sampling period extended over several days; for the smaller lakes and less important ponds, sampling occupied one day or part of a day. It follows that the analyses represent conditions at a particular time of the year and indicate only one phase—although, perhaps, the most important one—of the four-fold annual cycle.

In classifying the analyses in the tables which follow, the results for each determination are presented in ranges which seem appropriate to the purpose of that determination. This has been done largely for convenience in discussing the data. Those who have studied any large number of lakes are acutely aware of the nebulous line which divides any arbitrary grouping and it should be remembered that in any classification of such analyses the maximum of one group closely approaches the minimum of the succeeding group. Since bottom waters are usually the least favorable, chemically, for fish life, surface and intermediate data have been omitted from the present paper.

*Depth* (*Table 1*)*:* The depth of a lake or pond bears an important relationship to fish life. Not only the temperature but also the gaseous values are directly affected. In general, the limiting characteristics during the summer months are that a shallow water, unless fed by cold springs or tributaries, is warm throughout while a deep water is stratified into three layers with respect to temperature and gaseous relationships. Waters of intermediate depth may exhibit a gradual temperature gradient or may take on the characteristics of either of the other groups.

TABLE 1. DEPTH IN FEET

| Watershed / Range | | Champlain | St. Lawrence | Oswegatchie and Black River | Upper Hudson | Raquette | Summary |
|---|---|---|---|---|---|---|---|
| 1-10 | No. | 0 | 39 | 22 | 26 | 23 | 110 |
| | % | 0.0 | 41.0 | 15.7 | 17.1 | 21.1 | 21.4 |
| 11-20 | No. | 3 | 21 | 64 | 44 | 35 | 167 |
| | % | 17.6 | 22.1 | 45.7 | 28.9 | 32.1 | 32.6 |
| 21-40 | No. | 7 | 22 | 34 | 50 | 26 | 139 |
| | % | 41.2 | 23.2 | 24.3 | 32.9 | 23.8 | 27.1 |
| 41-60 | No. | 2 | 10 | 12 | 16 | 11 | 51 |
| | % | 11.8 | 10.5 | 8.6 | 10.5 | 10.2 | 9.9 |
| 61-100 | No. | 2 | 3 | 7 | 13 | 13 | 38 |
| | % | 11.8 | 3.2 | 5.0 | 8.6 | 11.9 | 7.4 |
| Over 100 | No. | 3 | 0 | 1 | 3 | 1 | 8 |
| | % | 17.6 | 0.0 | 0.7 | 2.0 | 0.9 | 1.6 |
| Total | | 17 | 95 | 140 | 152 | 109 | 513 |

In the St. Lawrence watershed, 41 per cent of the 95 lakes and ponds studied are less than 11 feet deep while for the Oswegatchie and Black River system some 46 per cent of the 140 waters studied are between 11 and 20 feet deep. Approximately 10 per cent of each watershed's waters are in the 41-60 feet range. Over 80 per cent of the 513 lakes and ponds studied are less than 41 feet in depth and less than 2 per cent are deeper than 100 feet.

*Temperature of Bottom Waters (Table 2):* Bottom temperatures in the deeper portions are an important factor in determining whether certain species, such as the lake trout, may be stocked profitably. This determination also governs the oxygen capacity of the water. The solubility of oxygen increases as the temperature of the water decreases. Moreover, the lower the temperature, the slower is decomposition of organic matter with its attendant consumption of oxygen. The color of the water affects bottom temperatures to a considerable degree. Due to marshy drainage, many Adirondack waters are brown. In such instances, most of the heat from the sun's rays is absorbed in the surface layer and the lower portions have a lower temperature than those of analagous white water ponds through which the sun's rays are more freely transmitted. Many examples could be cited of shallow, brown water ponds which have satisfactory bottom temperatures for trout while neighboring white water ponds have temperatures virtually the same throughout their depth.

One hundred and two or 20 per cent of the waters studied exhibit bottom temperatures in the lowest range of 40.0-50.0° F. Of these, the Upper Hudson watershed accounts for almost half. The largest percentage, over 37 per cent, lie in the 50.1-60.0° F. range with the Oswegatchie and Black River system accounting for one-third or 64 of the 191 found. The remainder, over 40 per cent, are divided among the warmer and very warm lakes and ponds.

TABLE 2. TEMPERATURE OF BOTTOM WATERS IN DEGREES FAHRENHEIT

| Watershed | | Champlain | | St. Lawrence | | Oswegatchie and Black River | | Upper Hudson | | Raquette | | Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 40.0-50.0 | No. | 5 | | 6 | | 20 | | 42 | | 29 | | 102 | |
| | % | | 29.4 | | 6.3 | | 14.3 | | 27.6 | | 26.6 | | 20.0 |
| 50.1-60.0 | No. | 7 | | 38 | | 64 | | 50 | | 32 | | 191 | |
| | % | | 41.2 | | 40.0 | | 45.7 | | 32.9 | | 29.4 | | 37.2 |
| 60.1-70.0 | No. | 5 | | 39 | | 32 | | 40 | | 34 | | 150 | |
| | % | | 29.4 | | 41.1 | | 22.9 | | 26.3 | | 31.2 | | 29.2 |
| Over 70.0 | No. | 0 | | 12 | | 24 | | 20 | | 14 | | 70 | |
| | % | | 0.0 | | 12.6 | | 17.1 | | 13.2 | | 12.8 | | 13.6 |
| Total | | 17 | | 95 | | 140 | | 152 | | 109 | | 513 | |

*Free Carbon Dioxide and Methyl Orange Alkalinity of Bottom Waters* (*Tables 3 and 4*): Carbon dioxide may be reported as free, half-bound or fixed. Only the free and half-bound are directly utilized for photosynthetic activities. Indirectly, the amount of fixed carbon dioxide is also important since the amount of half-bound is dependent on it. Phenolphthalein alkalinity is so uncommon in the Adirondack area, at any depth during the summer period, that carbon dioxide has been expressed as parts per million of free $CO_2$ and the alkalinity as methyl orange alkalinity in parts per million of $CaCO_3$.

Three factors operate for the accumulation of bottom free carbon dioxide from decomposition and respiratory processes. Stratification seals off the bottom layer and prevents a loss to the air; diffusion to the upper waters is very slow; light, which is necessary for photosynthetic consumption to take place, is greatly reduced or absent. It is not until the autumn period of circulation that this accumulated carbon dioxide is distributed.

TABLE 3. FREE CARBON DIOXIDE OF BOTTOM WATERS IN PARTS PER MILLION

| Watershed | | Champlain | | St. Lawrence | | Oswegatchie and Black River | | Upper Hudson | | Raquette | | Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Alkaline | No. | 0 | | 0 | | 0 | | 1 | | 0 | | 1 | |
| | % | | 0.0 | | 0.0 | | 0.0 | | 0.6 | | 0.0 | | 0.2 |
| Under 5.0 | No. | 12 | | 31 | | 18 | | 48 | | 31 | | 140 | |
| | % | | 70.5 | | 32.7 | | 12.9 | | 31.6 | | 28.4 | | 27.3 |
| 5.1-10.0 | No. | 2 | | 23 | | 30 | | 36 | | 20 | | 111 | |
| | % | | 11.8 | | 24.2 | | 21.4 | | 23.7 | | 18.4 | | 21.6 |
| 10.1-15.0 | No. | 2 | | 14 | | 18 | | 30 | | 21 | | 85 | |
| | % | | 11.8 | | 14.7 | | 12.9 | | 19.7 | | 19.3 | | 16.6 |
| 15.1-25.0 | No. | 1 | | 23 | | 44 | | 20 | | 22 | | 110 | |
| | % | | 5.9 | | 24.2 | | 31.4 | | 13.2 | | 20.2 | | 21.4 |
| Over 25.0 | No. | 0 | | 4 | | 30 | | 17 | | 14 | | 65 | |
| | % | | 0.0 | | 4.2 | | 21.4 | | 11.2 | | 12.8 | | 12.7 |
| Missing | No. | 0 | | 0 | | 0 | | 0 | | 1 | | 1 | |
| | % | | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.9 | | 0.2 |
| Total | | 17 | | 95 | | 140 | | 152 | | 109 | | 513 | |

In general, waters with high free carbon dioxide contents have low oxygen values. Associated investigators in this survey found that, of all trout ponds surveyed in the Upper Hudson area, only 7 had a free carbon dioxide value higher than 20 parts per million. The better ponds had 5.0 or less parts per million. Gutsell (1929) believes that 40 parts per million are not markedly harmful to trout.

Aside from the Champlain watershed, for which the data are probably too few to be certain they are typical, the St. Lawrence and Upper Hudson watersheds have the greatest percentages of lakes and ponds in the very low $CO_2$ range of 0-5.0 parts per million and account for over half the total. The Oswegatchie and Black River system has the fewest in this range as well as the highest percentage of high carbon dioxide waters. Almost half of all the lakes and ponds are in the 0-10.0 parts per million range while fewer than 13 per cent contain more than 25.0 parts per million.

**TABLE 4. METHYL ORANGE ALKALINITY OF BOTTOM WATERS IN PARTS PER MILLION $CaCO_3$**

| Watershed | | Champlain | | St. Lawrence | | Oswegatchie and Black River | | Upper Hudson | | Raquette | | Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Phenolph. alk. | No. | Too few data to classify. See note below. | | 1 | | 0 | | 1 | | 0 | | 2 | |
| | % | | | | 1.1 | | 0.0 | | 0.7 | | 0.0 | | 0.4 |
| 1.0-10.0 | No. | | | 41 | | 76 | | 53 | | 51 | | 221 | |
| | % | | | | 43.1 | | 54.3 | | 34.9 | | 46.8 | | 44.6 |
| 10.1-20.0 | No. | | | 29 | | 39 | | 61 | | 36 | | 165 | |
| | % | | | | 30.5 | | 27.8 | | 40.1 | | 33.0 | | 33.3 |
| 20.1-40.0 | No. | | | 22 | | 18 | | 24 | | 19 | | 83 | |
| | % | | | | 23.2 | | 12.9 | | 15.8 | | 17.4 | | 16.7 |
| 40.1-80.0 | No. | | | 3 | | 4 | | 8 | | 3 | | 18 | |
| | % | | | | 3.2 | | 2.9 | | 5.2 | | 2.8 | | 3.6 |
| 80.1-100.0 | No. | | | 0 | | 0 | | 0 | | 0 | | 0 | |
| | % | | | | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 |
| Over 100.0 | No. | | | 0 | | 2 | | 5 | | 0 | | 7 | |
| | % | | | | 0.0 | | 1.4 | | 3.3 | | 0.0 | | 1.4 |
| Missing | No. | | | 0 | | 1 | | 1 | | 0 | | 2 | |
| | % | | | | 0.0 | | 0.7 | | 0.7 | | 0.0 | | 0.4 |
| Total | | | | 95 | | 140 | | 152 | | 109 | | 496 | |

NOTE—Bottom alkalinities of Lake Champlain varied from 77.0 p.p.m. near Whitehall to 35.0 p.p.m. at the Gut. Bottom alkalinities of 5 other lakes ranged 3.0-21.0 p.p.m.

The bottom methyl orange alkalinity of almost half those recorded falls in the very low 1-10.0 p.p.m. $CaCO_3$ range. Practically 95 per cent have values less than 40.1 while less than 1.5 per cent have values greater than 100 parts per million. Only 7 of the waters studied exhibited phenolphthalein alkalinity at any depth; of these, only 2 did so in the bottom samples.

*Dissolved Oxygen of Bottom Waters* (*Table 5*)*:* The most important, single, chemical determination of a lake or pond is that of dissolved oxygen. Surface waters, as a general rule, contain an

amount of dissolved oxygen which often approaches saturation and occasionally exceeds it. This is not necessarily true, however. For example, Black Pond, 12 feet deep, in the Raquette drainage, has a surface water only 46.2 per cent saturated. Red bellied dace are fairly abundant. In bottom waters, the depth and character of the bottom are ruling factors. For shallow ponds, circulation is usually sufficient to keep the bottom oxygen value high unless a bog bottom, for example, intervenes. For deep waters which are stratified, the bottom dissolved oxygen content may be good, poor or absent. The same factors, previously mentioned, which operate for an accumulation of carbon dioxide cause a decrease in the stock of oxygen with which the bottom layer began the summer period, after the spring circulating period ended. If this initial stock of dissolved oxygen is insufficient to withstand the inroads of decomposition and respiratory processes, the supply becomes low and, in many cases, vanishes.

TABLE 5. DISSOLVED OXYGEN OF BOTTOM WATERS IN PARTS PER MILLION

| Watershed | Champlain | | St. Lawrence | | Oswegatchie and Black River | | Upper Hudson | | Raquette | | Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 0.0 | 0 | 0.0 | 9 | 9.5 | 20 | 14.3 | 19 | 12.5 | 24 | 22.0 | 72 | 14.0 |
| 0.1-1.0 | 1 | 5.9 | 15 | 15.8 | 32 | 22.9 | 37 | 24.4 | 22 | 20.2 | 107 | 20.8 |
| 1.1-2.0 | 3 | 17.6 | 4 | 4.2 | 15 | 10.7 | 14 | 9.2 | 6 | 5.5 | 42 | 8.2 |
| 2.1-3.0 | 2 | 11.8 | 9 | 9.5 | 15 | 10.7 | 14 | 9.2 | 5 | 4.6 | 45 | 8.8 |
| 3.1-4.0 | 2 | 11.8 | 8 | 8.4 | 18 | 12.9 | 7 | 4.6 | 10 | 9.2 | 45 | 8.8 |
| 4.1- 5.0 | 1 | 5.9 | 10 | 10.5 | 11 | 7.9 | 9 | 5.9 | 9 | 8.2 | 40 | 7.8 |
| 5.1-6.0 | 1 | 5.9 | 1 | 1.1 | 8 | 5.7 | 11 | 7.2 | 17 | 15.6 | 38 | 7.4 |
| 6.1-8.0 | 3 | 17.6 | 21 | 22.1 | 17 | 12.1 | 32 | 21.1 | 16 | 14.7 | 89 | 17.4 |
| Over 8.0 | 4 | 23.5 | 18 | 18.9 | 3 | 2.1 | 9 | 5.9 | 0 | 0.0 | 34 | 6.6 |
| Missing | 0 | 0.0 | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 |
| Total | 17 | | 95 | | 140 | | 152 | | 109 | | 513 | |

While the amount of dissolved oxygen necessary to fish life depends on the temperature, the species and other factors, for purposes of discussion we may take 2.0 parts per million or less as a very poor natural habitat value and 3.1 parts per million or greater as adequate for bottom waters. During the summer period, 43 per cent of the lakes and ponds studied had bottom dissolved oxygen values of 2.0 parts per million or less, including 14 per cent with

none. 48 per cent were in the range above 3.0 parts per million, including 24 per cent in the range above 6.0. Almost 7 per cent had bottom dissolved oxygen values of 8.0 parts per million or more. These include such outstanding, deep waters as Lake Champlain, Lake George, Lake Placid and Schroon Lake. The volume of water below the thermocline is large in proportion to that above it.

*Hydrogen Ion Concentration* (*Table 6*): From the work of associated investigators in the survey and others, it appears that fishes, in their natural habitat, tolerate a wide range in pH. In general, a low or acid pH is accompanied by other evidences of excessive decomposition, such as low dissolved oxygen and high free carbon dioxide values. Little Simon Pond, in the Raquette drainage, is an interesting exception. Its pH range is 5.2-5.4 with good chemical values and good fish collections. Ponds as acid as 4.4 are present in the Adirondack area. For these, no fish were collected, seen or reported although the accompanying, very poor, gaseous relationships are probably a contributing factor in making these waters unsuitable. Plankton studies indicate that lakes in the alkaline range have been the more productive due to the utilization of free and half-bound carbon dioxide. As with the gaseous constituents, it is only during the circulating periods that the hydrogen ion concentration is the same throughout a deep water. Ordinarily, bottom waters have a lower pH than that of the surface.

TABLE 6. HYDROGEN ION CONCENTRATION OF BOTTOM WATERS pH

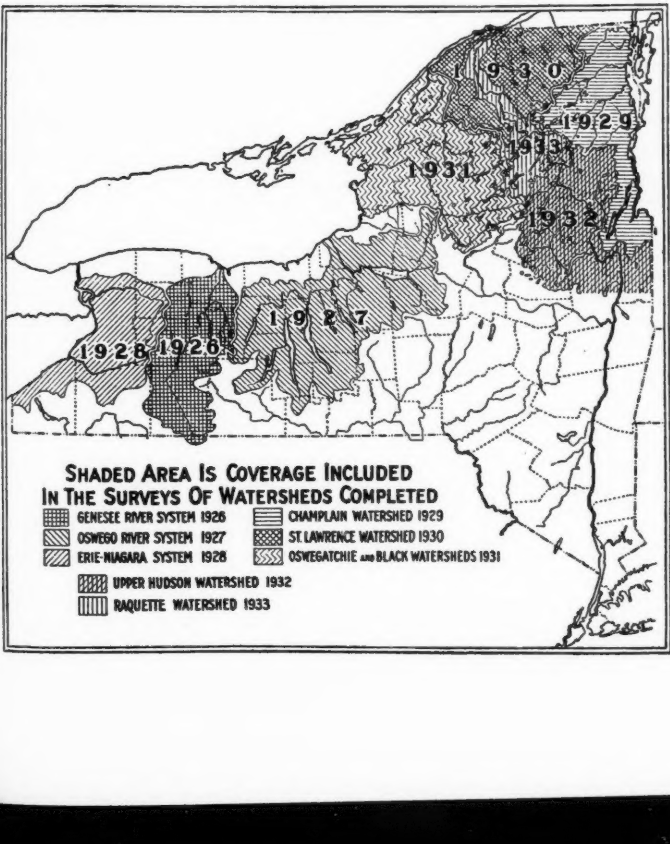
| Watershed | | Champlain | | St. Lawrence | | Oswegatchie and Black River | | Upper Hudson | | Raquette | | Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Under 6.1 | No. | Too few data to classify. See note below. | | 56 | | 97 | | 73 | | 56 | | 282 | |
| | % | | | | 58.9 | | 69.3 | | 48.0 | | 51.4 | | 56.9 |
| 6.1-6.8 | No. | | | 30 | | 36 | | 63 | | 39 | | 168 | |
| | % | | | | 31.5 | | 25.7 | | 41.4 | | 35.8 | | 33.9 |
| 6.9-7.1 | No. | | | 4 | | 3 | | 10 | | 9 | | 26 | |
| | % | | | | 4.2 | | 2.1 | | 6.6 | | 8.2 | | 5.2 |
| 7.2-7.9 | No. | | | 3 | | 4 | | 4 | | 5 | | 16 | |
| | % | | | | 3.2 | | 2.9 | | 2.6 | | 4.6 | | 3.2 |
| 8.0-8.6 | No. | | | 1 | | 0 | | 1 | | 0 | | 2 | |
| | % | | | | 1.1 | | 0.0 | | 0.7 | | 0.0 | | 0.4 |
| Over 8.6 | No. | | | 1 | | 0 | | 1 | | 0 | | 2 | |
| | % | | | | 1.1 | | 0.0 | | 0.7 | | 0.0 | | 0.4 |
| Total | | | | 95 | | 140 | | 152 | | 109 | | 496 | |

NOTE:—Bottom samples of Lake Champlain ranged 7.6-8.0. Bottom samples of 4 other lakes ranged 6.3-7.0.

Over 90 per cent of the Adirondack lakes and ponds studied have bottom values, during the summer, below the neutral range of 6.9-7.1, including almost 57 per cent below 6.1. 5.2 per cent may be said to be neutral and the remainder, 4 per cent, are in the alkaline range above 7.1. Of these latter, only 0.4 per cent lie above 8.6.

## THE NORTHERN NEW YORK OR ADIRONDACK AREA

| Year | Watershed | Principal Drainage |
|---|---|---|
| 1929 | Champlain | Lake Champlain, Lake George, the Mettawee, Bouquet, Ausable, Saranac and Chazy River systems. |
| 1930 | St. Lawrence | St. Lawrence (between Ogdensburg and the International boundary), the Grass, St. Regis, Schroon and Chauteaugay systems. |
| 1931 | Oswegatchie and Black River | Oswegatchie, Black, St. Lawrence (between Cape Vincent and Ogdensburg) and the lesser tributaries of the upper St. Lawrence and of northeastern Lake Ontario. |
| 1932 | Upper Hudson | Hudson River (to the Hoosic), Sacandaga, Schroon, Indian, Cedar and Opalescent systems. |
| 1933 | Raquette | The Raquette River system. |



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## Discussion

Mr. Markus: How does Dr. Faigenbaum account for the supersaturation in the lakes in which that condition prevails? Is it the presence of vegetation?

Dr. Faigenbaum: Yes, either the presence of vegetation or excellent aeration such as occurs under a waterfall. That, of course, is an unstable condition.

Mr. M'Gonigle (New Brunswick): What was the highest pH you discovered in your methyl alkalinity?

Dr. Faigenbaum: The highest pH, as I remember it, is 9.3.

Mr. M'Gonigle: In your methyl alkalinity, did you find that associated with photosynthesis, the utilization of carbon dioxide?

Dr. Faigenbaum: Yes.

# GROWTH AND HEREDITY IN TROUT

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Until quite recently it has been generally assumed that the great variation in the growth of trout, which is frequently so noticeable even under similar environmental conditions, is due almost entirely to the amount of available food. This belief has received wide acceptance in Europe, largely through the writings of Knut Dahl, the eminent Norwegian authority on trout and salmon.

In a paper on trout and trout waters in Norway, published in 1918, this authority definitely states that the growth of trout appears always to be a product of exterior influences and that no trout may apparently be considered as possessing definite and hereditary capacities for a definite kind of growth.

In reaching this conclusion Dahl was greatly influenced by the fact that there is a remarkable difference in the rate of growth of trout on the east and west slopes of the mountains of Norway. On the east slope the streams and lakes are rich in food and the trout grow rapidly, while on the western slopes food is less abundant and the rate of growth much slower. When trout are transferred from the western to the eastern slope, however, they grow as rapidly as fish which are indigenous to this region.

Another factor influencing growth, which receives great prominence in Dahl's writings, is the size of the egg. He finds that the growth of young trout is proportional to the size of the eggs, and that the size of the fish at birth is, on the average, the most important factor in its subsequent growth. Fish having but a small amount of yolk when hatched grow, under otherwise similar conditions, much slower, on the average, during the whole of their life than fish born with a large amount of yolk. Furthermore, Dahl contends that the size of the egg is largely dependent on the growth and age of the mother fish.

If, therefore, trout live under overcrowded or other conditions which compel them to spawn at a small size, or when very young, they will produce numerous and small ova which will in turn produce young with a propensity for slow growth. The result is a vicious circle in which each generation tends to grow smaller and smaller. If, however, conditions favor a rapid growth, or the fish are unable to spawn until reaching a greater age and, as a consequence reach a larger size, the young will be larger and more vigorous and will therefore show a propensity for more rapid growth, provided conditions are otherwise equal.

If Dahl's contentions are true it would appear that the trout culturist desiring to obtain maximum growth among his fingerlings should use only eggs from old fish that have been fed all they will eat and, consequently, lay larger eggs.

Recently Southern, in a paper on the food and growth of brown trout, has discussed the growth of wild trout in Ireland at considerable length. The trout waters of this country may be divided into two fairly well defined types: limestone waters in which trout grow rapidly and attain a weight of one to four pounds, and acid waters where trout grow slowly and seldom exceed one-quarter to one-half pound in weight. Southern believes that the evidence indicates that acid waters produce small, early-maturing, short-lived trout, while alkaline waters produce large, late-maturing, long-lived fish.

This striking difference in the type of trout produced in acid and alkaline waters is not believed, however, to be due to the direct action of the physical and chemical environment nor to a difference in size of eggs, since small trout in acid water produce eggs which are relatively larger than those from trout in alkaline waters. In fact Southern differs from Dahl in concluding that "it would appear that in waters where for some reason the environment is unfavorable for rapid growth and where the trout are small and growth is slow, natural selection has resulted in the evolution of trout having the capacity to produce large ova from which large fry develop, thereby ensuring to the fry a good start in the struggle for existence in an environment unfavorable to growth."

On the other hand, since it has been shown that trout when transferred from acid to alkaline waters grow much more rapidly Southern concludes that the difference in rate of growth cannot be due to heredity but to some external factor. Aside from the direct action of the physical and chemical environment, it is obvious that the most important external factor is the food supply. This may vary both in quantity and in kind, and unlike most other writers Southern appears inclined to lay more stress on the character of the food than on the amount. He states that studies of the relative amount of food in stomachs of fish from different waters lends no support to the view that sizes and growth rate of trout depend directly on the amount of food consumed. In some instances small trout from acid waters had a greater proportionate amount of food in the stomach than fish from richer waters. He further states that "many waters, even where the trout are small, maintain large reserves of suitable trout food which are not availed of by the trout." Southern contends that trout appear to tire of one particular kind of food which is continuously present in large quantities and eagerly consume other kinds, the supply of which is intermittent.

I have thought it advisable to consider the writings of Dahl and Southern in considerable detail since their views appear to be representative of the prevailing attitude among European writers re-

garding the factors which regulate the growth of trout. It is true that the views of Dahl and Southern differ quite radically in several respects, but it is also true that they agree in holding that the rate of growth in trout is determined by the environment, and that heredity has little or nothing to do with it. Even among European writers, however, there are some who question the supreme importance of food and the size of eggs in the growth of trout, but apparently little effort has been made to determine experimentally the truth or falsity of these views.

I do not believe that American trout culturists have any doubts as to the great importance of the amount and character of the food in influencing the growth rate of trout. This fact has been demonstrated time and time again by carefully controlled experiments which show that under identical conditions the growth of trout on certain diets may be two or three times that on other diets. On the other hand, it has also been demonstrated experimentally that trout on the same diet often show marked differences in the rate of growth, and I believe that these differences can in many cases be shown to be inherited.

According to Hayford and Embody (1930) breeding experiments with brook trout started in 1919 at the New Jersey State Hatchery at Hackettstown have resulted in marked increase in the rate of growth as well as greater resistance to disease and higher egg production. In four generations the maximum length of the fish at the end of the second year increased from 10 inches to 13.75 inches, while the minimum length increased from 7 to 10.5 inches, and they state that it is now possible to have trout for stocking purposes averaging between 6 and 7 inches long at the end of the first summer instead of the usual 3-, 4-, and 5-inch fingerlings. These results were accomplished by selecting a small percentage of the most rapidly growing fish in each generation for breeding purposes.

The breeding experiments conducted by the U. S. Bureau of Fisheries at the Pittsford (Vermont) experimental hatchery have been carried on in a somewhat different manner. Each season a number of select fish are mated and the progeny of each pair reared separately during the following summer. In selecting these fish special emphasis is placed on rapid growth, vigor, fecundity, body symmetry, and coloration.

In order to rear all the experimental lots under as nearly identical conditions as possible during the first summer, an equal number of fish is taken at random from each lot and placed in a separate compartment. These compartments are all of the same size and made by inserting screens in the troughs so that each trough is divided into three sections. The young trout are held in these compartments through the summer and are, of course, given the same food in all cases.

In September the lots which excel in growth, vigor, and other

qualities are removed to pools where they are reared to maturity. The best fish from these lots are mated to produce the next generation. Owing to the low temperature of the water the fish do not grow as rapidly as at Hackettstown, and eggs for experimental purposes are not taken until the end of the third year. Fish of this age are usually known as two-year old breeders, but are three years old if reckoned from the date of impregnation of the eggs. Many of the males used in the experiments are a year younger than the females.

From the very beginning of these experiments there has been a marked difference in the rate of growth of the young of different pairs. Although the fish were in all cases selected for their superior size as well as other characteristics, the young of certain pairs grew two or three times as fast as the young of other parents. For instance, in 1928 the fastest growing lot of fingerlings averaged 7.3 grams in weight while the slowest growing lot averaged only 2.0 grams each. The other lots were intermediate between these two extremes. In the following year, 1929, the largest fingerlings averaged 7.7 grams while the smallest again showed an average weight of only 2.0 grams. In 1930 the largest fish showed an average weight of 7.8 grams at the end of the season. The smallest fish this year were somewhat larger with an average weight of 3.7 grams. Again in 1931 the largest fish reached an average weight of 7.4 grams in September while the smallest averaged 3.2 grams.

It is, I think, a remarkable fact that in each of these years the weights of the fish from selected parents was within practically the same range. The maximum size was approximately the same each year although the minimum size increased from two to over three grams.

During the season of 1932 eggs were available for the first time from the second generation of selected fish, and we find that the fastest growing lot of fingerlings reached an average weight of 12.7 grams in September. A second lot averaged 12.0 grams in weight, while 3 lots showed an average weight of over 10 grams. The smallest fish, on the other hand, averaged 4.9 grams in weight.

Part of this increased growth was, no doubt, due to the use of a better diet in 1932, but that it must have been in large part the result of selection is shown by the fact that the fastest growing lot in our feeding experiments for this year reached an average size of only 6.1 grams. This was less than one-half the size of the largest fingerlings from specially selected parents.

Moreover, the wide range in the rate of growth of different lots can only be explained on the basis of heredity. Since all lots were kept under as nearly identical conditions as possible and fed all they would eat of the same food the only explanation of the difference in size is an inherent capacity for growth.

Additional evidence that rate of growth in trout is controlled to

a large extent by heredity is furnished by an experiment conducted at the Leetown (W. Va.) station in 1933. In this experiment three lots of brook trout of different ancestry were reared under as nearly identical conditions as possible with respect to food and water supply. Each lot, containing 1,200 fingerlings, was placed in a standard hatchery trough on March 1, where the fish remained until the experiment was discontinued. Two lots of fish were from eggs taken at the York Pond (N. H.) station. One lot of these eggs was from fish that had been reared from wild stock; the second lot from fish still further removed from their original wild ancestors. The third lot of eggs was taken from selected stock at the Pittsford station.

From the beginning of the experiment, the fish from the Pittsford stock grew much more rapidly than those from the York Pond station. There was practically no difference in the growth of these two lots of fish. The experiment was discontinued in August when the fish in each lot were 29.5 weeks old. At this time the average weight of the Pittsford fish was 14.5 grams while that of the two lots of York Pond fish was 4.9 and 4.6 grams, respectively. There was also a marked difference in mortality in favor of the Pittsford fish, although the losses were abnormally high in all three lots. This was no doubt largely due to the fact that no attempt was made to lessen the mortality by the use of control measures.

To what extent the rate of growth can be increased by selective breeding is, of course, a matter for conjecture. It is evident that there must be a limit to the increased growth which can be obtained by this means, but it is scarcely probable that this limit has been reached in two generations of rigid selection. The progress already made is truly remarkable, and it is now possible by the use of selected stock and improved diets to rear brook trout in one year to a size which ordinarily requires from three to four years under natural conditions. In fact, at temperatures which are most favorable for growth it is possible to rear brook trout to a length of 9 to 10 inches by the end of the first summer.

So far the experiments in selective breeding have dealt chiefly with brook trout, but similar experiments with rainbow and brown trout are now in progress. The results so far obtained indicate that these species are just as responsive to selection as is the brook trout.

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## Discussion

MR. CATT (New Brunswick): We have been carrying out some experiments in the hatchery at Antigonish, Nova Scotia. We found that fingerlings from wild trout hatched in April weighed 7.7 ounces to the hundred on the 26th of September. The second generation, selected from the quickest growing wild trout, weighed 19.2 ounces per hundred. The ordinary hatchery stock, which is selected, weighed 32.5 ounces per hundred, and the quickest growing selected hatchery stock weighed 50.5 ounces per hundred.

# EFFECT OF HEREDITY ON THE GROWTH OF BROOK TROUT

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At the meeting of this Society held at Baltimore two years ago the writer presented a paper entitled "Some Things We Think We Have Learned at York Pond." Three paragraphs of this paper were devoted to a comparison of the relative growth of brook trout fingerlings hatched from the eggs of native brood fish, a few generations by careful selection from wild foundation stock, and from commercial eggs which had probably received no infusion of wild blood for twenty-five generations. The weights secured at that time follow:

| | |
|---|---|
| Weight of 100 native fingerlings | 1½ pounds |
| Weight of 100 fingerlings from commercial eggs | 2½ pounds |

During the discussion which followed the paper, Commissioner Brown of Vermont presented similar weights from one of his hatcheries where fish from York Pond eggs were being fed. Though his weights on each lot were considerably greater than those secured at York Pond, there was relatively about the same comparison between the fish from York Pond eggs and those from commercial eggs.

During the spawning season of 1933 the fish from which the above weights were secured were both inbred and outbred. During the present feeding season lots of 2,000 from each of these breedings have been handled under identical conditions. A comparison of the weight of 500 fish from each lot, made August 22, follows:

| | |
|---|---|
| Commercial fish inbred | 1 pound, 13 ounces |
| York Pond fish outcrossed with commercial males | 1 pound, 9 ounces |
| York Pond fish outcrossed with commercial females | 1 pound, 4 ounces |
| York Pond fish inbred | 1 pound, 3 ounces |
| A similar lot from eggs from newly captured wild fish | 1 pound, 1 ounce |

The small growth these fish had made is explained by the fact that they were fed in small troughs supplied from flowing wells with a water temperature of approximately 46 degrees F. The weights, too, were secured several weeks earlier in the season than those presented at Baltimore. Also, the eggs from which the fish were hatched came from young adults, with a count of approximately 600 per ounce as compared with a station average of approximately 350. At this time fish of similar age in outside raceways and ponds, under varying conditions, weighed from 4 to 9 pounds per 500.

Other fish culturists have noted the slow growth of brook trout from wild eggs as compared with those from fish held long under domestication. More than 30 years ago the late Mr. John W. Titcomb exchanged wild for domesticated eggs with a commercial fish culturist.

It was complained that almost no growth was secured with the resulting fish from the wild eggs. The Maine Department of Fisheries and Game has at times fed trout hatched from eggs from wild fish taken at the Rangely Lakes. It is well known that these lakes produce the largest brook trout taken in the East. Yet I have been told that no satisfactory growth has been secured from them.

How is this matter to be explained? Shall we assume that the domesticated fish have inherited an ability to make rapid growth? Or shall we rather ascribe it to the shyness of the wild and semi-wild fish —a shyness which half a dozen generations have failed to remove? Instead of coming eagerly to the attendant for their food, as do the fully domesticated fish, they waste their energy in dashing wildly about the raceway. When, however, they have lost their shyness, after some months, their rate of growth is fully equal to that of the domesticated fish. In some cases, indeed, during the second summer they have caught up with and even outstripped the fish which had so greatly distanced them during the first summer.

It will be noticed from the table of weights that the influence of the males in the outcrossings seems to be greater than that of the females. The evidence is hardly conclusive, however, since only single lots of each breeding are compared. The better growth could, perhaps, have resulted from better individual male than female fish in the parentage. It is of interest in this connection that in any given lot of fish selected for rapid growth the males far outnumber the females. This indicates that males grow more rapidly than females and they may transmit this tendency to their offspring.

In view of this indication, as far as possible, domesticated males will be used in our spawning operations during the coming season.

# PROPAGATING DAPHNIA AND OTHER FORAGE ORGANISMS INTENSIVELY IN SMALL PONDS

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In the spring of 1924 the late Dr. A. Brooker Klugh, formerly of Queens University but at the time residing in Ithaca, New York, had mailed to him some living specimens of *Daphnia magna* collected in Canadian waters. He nursed them along in small aquaria containing a certain culture medium until there must have been several thousands. These first few individuals constituted the nucleus of the strain we now have from which cultures have been widely distributed to eastern hatcheries.

The present paper deals with our efforts over the past ten years to maintain sufficient quantities for feeding during the normal growing period of warm water fish.

For the first few years we tried to keep cultures going continuously throughout the summer in the same pond, merely adding from time to time a definite amount of fertilizer. The result was that very successful cultures were maintained during May and part of June which always ran out in July but seemed to come back in late September and October.

The more important causes for the diminishing supply seemed to be the population density; the accumulation of waste products not only from the daphnia themselves but from the micro-organisms also present; predatory enemies of daphnia and probably water temperatures somewhat above 82° F. All of these factors have been mentioned before by various investigators, especially by Dr. A. M. Banta and his associates, who from time to time have made many very important contributions to the knowledge concerning these small crustacea. All of the above mentioned factors except predatory enemies have been shown by them to favor the production of so-called winter eggs, which is usually an indication that the culture is on the wane.

In order to have strong cultures at all seasons it becomes necessary to keep the individual daphnia in the active condition of producing asexual or so-called summer eggs only, which demands the elimination of the inhibitive factors just mentioned.

A too dense population of course is easily reduced by feeding the daphnia. The excessive accumulation of waste matter is corrected by a change of water in the pond. Predatory enemies are controlled partly by sterilizing the pond bottom and sides immediately before starting a culture and later by spraying the surface with some nontoxic animal oil, such as herring oil, salmon oil, or cod-liver oil.

The water temperature cannot be controlled and consequently where it ranges above 82° F., for any length of time, it may be difficult or impossible to produce cultures of *Daphnia magna*.

A population density reaches the maximum under the experimental conditions maintained in our ponds in from sixteen to twenty-six days with the water temperature varying between 70° and 80° F. We have taken twenty-one days as the average period. Consequently cultures are permitted to develop for twenty-one days, when they are fed to the fish and an entirely new culture with fresh water is started. The schedule of operations is as follows:

First Day—Pond is drained, bottom and sides thoroughly disinfected with a strong solution of chlorinated lime; allowed to stand six hours, then refilled, fertilized and stocked with large daphnia from an active culture.

Fifth to Seventh Day—Second fertilization.

Tenth to Fourteenth Day—Third fertilization.

Twenty-first Day—Drawing the pond and feeding the daphnia. Subsequent sterilization, refilling, refertilization and stocking with active daphnia.

In general this routine was continued through several summers from May to October and when the proper amount and kind of fertilizer was administered, the results were consistently good.

## Associated Food Organisms

Although we have tried to maintain pure cultures of daphnia, other organisms have naturally appeared and multiplied. Some of these are desirable food animals but others are predators.

Several little hard shelled crustacea, known as *Ostracods,* have appeared in considerable numbers, especially late in the culture period. Some fishes will not feed on them but we find that our bass and bullhead fingerlings devour them about as readily as they do the daphnia. We believe there is some connection, however, between their abundance and a decline in the production of daphnia without as yet having direct evidence that they actually prey upon living daphnia. Disinfection of the pond does not entirely eliminate them but nevertheless helps to keep them under control.

Midges of the genus *Chironomus* are attracted to the pond within a day or two after adding fertilizer, probably by the odors of fermentation, and deposit enormous numbers of eggs. These, as will be seen later, add considerably to the production of the pond. Mosquitoes likewise are attracted at about the same time and their characteristic floating egg masses become conspicuous all over the surface.

These three associated organisms may be considered beneficial insofar as they increase considerably the production of fish food. The mosquitoes, however, are obnoxious as adults and since they transform to the adult stage long before the daphnia culture reaches a peak, it is probably better to exterminate them with the nontoxic oil spray four to six days after the eggs appear. Other groups of animals

which almost invariably appear are the back swimmers, larvae of aquatic beetles, nymphs of dragon flies and damsel flies, and Hydra. All are predatory on daphnia and midges. It is well known that the oil spray kills all insects which have to come to the surface for air, such as the larvae of mosquitoes, beetles, and adult back swimmers. The dragon fly and damsel fly nymphs and Hydras are eliminated when the pond is drained and disinfected.

TABLE 1. AMOUNT OF FERTILIZER PER 100 CUBIC FEET OF WATER AND ITS APPORTIONMENT—(EXPERIMENTAL PONDS AT ITHACA, NEW YORK)

| Fertilizer | Soy Bean Meal | Cotton Seed Meal | Dry Buttermilk | Sheep Manure and Soy Bean Meal |
|---|---|---|---|---|
| Initial dose | 1 pint | 1 quart | ½ pint | 4 qts. Sh. M. 1 pt. B. M. |
| 2nd dose | 5th day—1 pt. | 7th day—1.5 pt. | 7th day—½ pt. | 14th day—½ pt. B. M. |
| 3rd dose | 10th day—1 pt. | 14th day—1.5 pt. | 14th day—½ pt. | |
| 4th dose | 15th day—½ pt. | | | |

Harvest on the 21st day.

## Fertilizers Used

Many different fertilizers have been tried, including manure from horses and cattle, dried sheep manure, acid phosphate, soy bean meal, cotton seed meal, dry buttermilk and alfalfa meal. The alfalfa meal produced only fair cultures and required such a large quantity of material that experiments were early discontinued.

The dried sheep manure used in combination with either acid phosphate or soy bean meal produced average cultures consistently. The wet animal manures were from ordinary barnyard piles containing much straw and slightly rotted. The resulting cultures were about average but not always dependable. The fresh cow manure without straw used so successfully by Mr. Hayford could not be obtained.

The fertilizers which gave cultures averaging the highest were dry buttermilk, soy bean meal, and cotton seed meal. Very little difference between them was noted. It happened that the densest culture (Table 2), amounting to 2,416.5 grams of daphnia, mosquito and midge larvae, was obtained in twenty-four days using one pint soy bean meal at the start and one pint every sixth day thereafter, making a total of two quarts for the period. This was in a concrete lined pond 8′ x 12′ with a water capacity of about 100 cu. ft., the water temperature varying between 70° and 80° F.

The data recorded in Table 2 have been secured in the operation of seven concrete propagating ponds. The water supply is controlled by dams in such a way that a constant level is automatically maintained in each pond without overflow. The water is therefore stagnant at all times. Each pond has an independent drain which leads directly into a bass-rearing pond. Hence all food organisms produced may be drained directly into the rearing-pond by removing a stand pipe. During the last four years it has been customary to operate them in rota-

tion, thus producing several crops in each during the summer season.

We desired to know something about the quantity of food organisms produced by different fertilizers during different periods and hence attempted to measure a few crops that varied from poor to perhaps the best.

TABLE 2. PRODUCTION OF FOOD ORGANISMS IN CONCRETE PONDS 8' x 12' WITH WATER CAPACITY OF 2,754 LITERS, EACH SET REFERRING TO THE PRODUCTION IN ONE POND FOR ONE PERIOD

| Fertilizer | Stocking Quantity of Daphnia | Period in Days | Production in Grams: Daphnia | Midges | Mosquitoes | Total |
|---|---|---|---|---|---|---|
| 4 qts. sheep manure, 1.5 pts. soy bean | ? | 15 | 695 | 150 | 0 | 845 |
| 4 qts. sheep manure, 1.5 pts. soy bean | ? | 16 | 690 | 25 | 0 | 715 |
| 5 qts. sheep manure, 1.5 pts. soy bean | ? | 20 | 407 | 309 | 442 | 1,158 |
| 4 qts. sheep manure, 1.5 pts. soy bean | ? | 21 | 462 | 77 | 0 | 539 |
| 4 qts. sheep manure, 1 pt. soy bean | ? | 22 | 706 | 308 | 0 | 1,014 |
| 1.75 pts. dry buttermilk | ? | 28 | 1,318 | 75 | 152 | 1,545 |
| 2 qts. cotton seed meal | 50 cc | 21 | 800.0 | 56.0 | 0 | 856.0 |
| 4 qts. cotton seed meal | 50 cc | 30 | 1,280.0 | 60 | 0 | 1,340.0 |
| 3 qts. cotton seed meal | ? | 30 | 1,060 | 460 | 0 | 1,520 |
| 1.25 qts. soy bean | 100 cc | 16 | 1,066 | 0 | 0 | 1,066 |
| 1.25 qts. soy bean | 25 cc | 17 | 1,386 | 0 | 0 | 1,386 |
| 2.25 qts. soy bean | 100 cc | 17 | 686 | 358.4 | 0 | 1,044 |
| 2.25 qts. soy bean | 50 cc | 17 | 335 | 1,092.16 | 0 | 1,427 |
| 2.25 qts. soy bean | 25 cc | 14 | 219 | 730.8 | 0 | 949.8 |
| 1.5 qts. soy bean | 50 cc | 20 | 1,759.5 | 369.4 | 0 | 2,128.9 |
| 1.25 qts. soy bean | 25 cc | 21 | 1,460 | 246.0 | 0 | 1,706.0 |
| 1.25 qts. soy bean | 100 cc | 21 | 613.7 | 1,104.0 | 0 | 1,717.7 |
| 2 qts. soy bean | 50 cc | 24 | 1,825.0 | 174.5 | 416.5 | 2,416.5 |

NOTE: One pound = 453.6 grams.

Each crop reported in Table 2 was removed by sweeping the pond slowly with large plankton nets of bolting cloth, transferring the catch frequently to a vessel of water. Finally the stand-pipe was removed and the remaining contents of the pond were drained through the net. This last catch contained some trash from the pond bottom, the coarser part of which was separated with a screen having a mesh large enough to permit the daphnia only to pass through.

The midge larvae and mosquitoes were picked out of the trash and also from the plankton catches by hand, a long tedious task. The smallest daphnia were lost, since they could not be separated from the finest particles of waste.

In this manner there was one vessel of water containing daphnia from medium to large size plus a small amount of sediment that could not be removed. We calculated that the daphnia which escaped compensated for the sediment retained. There was another vessel containing midges and a third containing mosquitoes. The cultures were then separately strained through bolting cloth and the contents thoroughly drained with slight pressure. Finally each mass was placed in a dry vessel and weighed. Undoubtedly there is some error in the method

but it is believed to be very small in comparison with the large amount of food material in one catch.

The first five sets of values (Table 2) were obtained after using a total of 21 quarts of dry sheep manure and seven pints of soy bean meal, giving a total of 4,271 grams of food organisms over a total period of ninety-four days or an average of 854 grams per pond of approximately 2,754 liters capacity during average period of 18+ days. This is at the rate of .31+ grams per liter.

The last nine sets of values refer similarly to the production with soy bean meal used alone showing a total of 13,841.9 grams of food produced over a total period of 167 days using 15.75 quarts of soy bean meal. This is an average of 1,338 grams of food per pond per period of 18+ days or at the rate of .558 grams per liter.

Hence with soy bean meal used alone nearly double the quantity of food has been obtained with only about 64% of the amount of fertilizer used in the case of sheep manure and soy bean meal combined.

Unfortunately we have not yet made a sufficient number of determinations with dry buttermilk or cotton seed meal to warrant a mathematical comparison with the other fertilizers. However, from general observations we are inclined to agree with Mr. Hogan (Trans. for 1933, p. 113) that cotton seed meal is one of the best fertilizers for the production of these fish food organisms.

Peak cultures seem to require from 30 to 50 per cent more cotton seed meal than soy bean meal and the culture period is somewhat longer with the former.

On the other hand, cotton seed meal, like animal manures, stains the water a deep brown, resulting in deeply colored red daphnia. The deep color seems also to prevent undue growth of blanket algae. The soy bean meal produces light gray daphnia and an abundance of free moving micro-algae which color the water green. It also encourages the growth of blanket algae.

It is well to point out that a pond containing fish cannot be fertilized as heavily as one in which food only is to be produced. The decomposition of so much fertilizer invariably lowers the oxygen below the critical point for bass. In fact, in some cases where one quart of soy bean meal per 100 cubic feet of water constituted a single dose even the midges and daphnia were killed. This was not the case, however, if the soy bean meal were fermented for a day or two before using.

## Stocking Ponds with Daphnia

The quantity of daphnia necessary to start a successful culture, within certain limits, is not so important as the physiological condition of the mother organisms. They should be active summer egg producers. Almost always a few will be found with winter eggs. If the proportion is large, specimens from such a culture should be dis-

carded. In the experiments reported here from 25 to 100 cc. of mother organisms were generally used. We believe that 50 cc. is sufficient for 100 cu. ft. of water. They are measured by pouring water containing daphnia into a tall graduate held in the sunlight. The individuals very soon settle to the bottom and the quantity may be determined with ease.

## Acknowledgments

Certain graduate students from time to time have assisted in gathering the experimental data upon which this paper is based. We are especially indebted to Messrs. O. R. Kingsbury and Gordon Trembley, who at different times have rendered valuable service.

# THE SPAWNING HABITS OF THE ATLANTIC SALMON*

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The spawning grounds of the Atlantic salmon are scattered along the entire course of the coastal rivers from the upper reaches to just above tidal waters. Here spawning takes place in late October and early November, the season varying yearly with climatic conditions. As a rule the early-run salmon occupy the upper and the late-run the lower waters, but not infrequently late-run salmon, by fast upstream progress, may occupy the same grounds as those which have entered the river months previously. Since the parr tend to remain in the particular section of the river where they have been hatched, nature has taken this method of offsetting over-population and deficiency in food supply by spreading the distribution of the parr over a wide area.

*Spawning Grounds:* The spawning grounds are in the shallow, swift-running water. The most suitable soil in the Canadian rivers is a coarse gravel, which contains many stones from 2 to 8 inches in size. Loose gravel or sand is unsuitable because of its shifting nature, while coarse gravel and stones not only afford protection to the buried eggs, but allow the penetration of well-aerated water. The beds must be located so as not to receive the full rush of the winter floods nor be exposed to the scouring action of the swift currents. While the female salmon may select any position in the river with suitable soil and flow, the majority of the beds are located near the banks of the river, where the flow of the water is broken. They are situated within a reasonable distance either above or below the pools where the female rests in the interval between depositing eggs.

In general, the requirements are a moderately swift current and stones heavy enough to resist a fairly strong flow of water, yet light enough to be moved by the salmon. Rivers vary greatly in the extent of the spawning grounds. The relative abundance of the deep pools, areas of slack water, and rapid runs with large rocks and an extremely swift current limit the areas available for spawning and in part determine the productive capacity of a river.

The depth of the water, which varies from 6 to 48 inches, should be sufficient to protect the bed from ice and the scouring action of the swollen currents. Instinct enables the salmon to select the correct depth, but it does not enable the salmon to recognize high or low water conditions in the rivers. During abnormally high

*Work carried on under the auspices of the Biological Board of Canada.

water, spawning beds are frequently located in places which, when the river returns to its normal level, are nearly or completely exposed. Seasons characterized by high water conditions tend to give a low hatch and constitute one of the causes of variation in the annual hatch in the rugged Canadian rivers. Nature endeavors to overcome this damaging feature by causing the salmon to cease spawning at the time of a freshet.

The redd or spawning bed is easily recognized by the lighter color of the newly exposed gravel and stones. At the upper end is a hollow, usually 3 by 2½ feet and some 8 inches deep, below which extends a mound of newly turned gravel and stones from 8 to 20 feet long and 2½ to 3 feet wide, resembling a newly filled, rounded grave. Its length depends upon the size of the female salmon, and whether two beds have joined each other. The fertilized ova lie in the interstices of the stones and coarse gravel at an average depth of 10 inches.

*Digging the Redd:* Previous to spawning, the female prepares the initial hollow for the reception of the eggs. The male has no share in this labor. This preparatory stage usually occurs shortly before the salmon is ready to extrude her eggs, but it has also been observed in females long before their eggs were ripe. The beds of these precocious females are only in the incipient or hollow stage and do not show the elongated grave-like mounds of gravel which indicate successive deposits of eggs.

The digging of the redd is an operation distinct from the act of spawning. It is usually stated that the salmon by turning on her side repeatedly churns up the gravel with her tail and deposits from 18 to 20 eggs at each turn, that this procedure occurs about every five minutes and that, when the redd reaches a depth of 6 to 12 inches, the female salmon begins to work upstream until, at the completion of spawning, the gravel has been turned over for a distance of about 9 feet.

Our observations indicate that digging is not usually accompanied by the extrusion of the eggs, at least not until a suitable hollow has been made. After the selection of a suitable site the female salmon begins the work of excavation by a vigorous action of the tail and body. She suddenly turns on either the right or left side, and arches the body in a crescent shape with the concave side toward the bed of the river, bending the head downward against the current. The entire body resembles the curve of a poorly made bow, the curve of the tail having a much longer slope than the more acute bend of the head. The tail, held at an acute or right angle to the current and bed of the river, comes close to or in contact with the gravel. The body is suddenly straightened, the long arm of the bow imparting a vigorous kick or "flit" to the tail. By this powerful movement a column of water is forced against the bottom sufficient to dislodge sand, gravel, and small stones, which

are rolled downstream by the action of the current. Although the salmon applies in rapid succession 5 or 6 of these forceful contractions and extensions of the body, little change can be observed in hard gravel.

The salmon, by intermittent digging, enlarges the hollow, working on the sides and upstream end. When digging in the upstream end, the tail is held at right angles to the bed. When digging on the sides of the hollow, it is held at a more acute angle. As a rule when excavating the right side of the redd, the salmon, headed upstream, turns on her right side and when digging on the left side of the bed, turns on her left side but she may use either side, irrespective of the section of the redd. The frenzied digging which follows the extrusion and fertilization of the eggs, is quite different from the leisurely digging in preparing the redd, when the salmon lies most of the time quietly on the bottom and digs at irregular intervals only.

Although thoroughly engrossed in the duty of digging the redd and depositing her eggs, the female salmon possesses a certain protective wariness, although occasionally it is possible to wade within a short distance of the redd without disturbing her. When frightened, she leaves the redd to return after a variable time when she has become accustomed to the strange object which caused her flight. The males return more quickly to the vicinity of the redd than the females.

*Mating:* It is the popular belief that the female salmon selects a single mate who remains with her during the entire spawning period. Our observations fail to substantiate such a premise. When ready to spawn, she selects a favored male and will aid him in chasing away other amorous males, although she will not go far from the redd. In making her choice she favors the large males and is intolerant of the small males and grilse. The favored male takes up his position directly downstream, a few feet below the female, moving occasionally from side to side. The protection of the redd appears his particular duty, since often he will remain near the redd after it has been temporarily deserted by the female. The role of favored male is not secure, since he may be supplanted at any time during the season, day, or hour. When there is a surplus of males on the spawning grounds, cruising males are constantly shifting from female to female, awaiting the crucial moment when they may share in the fertilization of the eggs. Within a period of 5 hours three different males may have been observed to occupy the position of favored lover, the larger cruising males driving off their smaller rivals and usurping their position. A similar observation with the brook trout is reported by Hazzard (1). Not infrequently two and even three males may temporarily occupy secondary positions below a female. Whenever surplus males are on hand, the favored male must share with others the privilege of

fertilizing the eggs. It is possible that at night, the favorite time for spawning, the number of surplus males may be materially reduced. The male grilse is the pest of the spawning grounds and is chased by both the male and the female salmon, as it darts swiftly around waiting for the opportunity to share in the spawning act, or possibly act as the sole male partner.

When salmon are numerous on the spawning grounds, particularly at night, the water is kept in constant turmoil by the activities of the males chasing invaders from their chosen females. Whether these rushes can be termed fighting is questionable. Usually it takes the form of a single rush, the attacking male attempting to strike the side of the offender with its head. Usually he is unsuccessful, since the wary opponent anticipates the rush and with a sudden swerve darts diagonally downstream pursued by the aggressor. Unless the offender has retired to a sufficient distance, the attacking male may make a second or even a third rush in rapid succession. When the attacking salmon reaches its opponent, it opens its jaw and gives the impression of biting, but the writer has never seen a salmon bite another, nor has he observed any salmon wounded by biting. The protruding hooked jaw of the male, instead of being a weapon for fighting, appears to be of disadvantage for quick seizure. The action of the female salmon in chasing undesirable males is similar, although less vigorous than that of the male, and her mouth seems to be a more efficient weapon than that of the male.

*The Spawning Act:* The favorite time for spawning is at night, but a few female salmon may be found at any time of day digging the redd or, rarely, depositing eggs. During the spawning season, numerous vacant redds may be seen during the day on the gravel bars.

The older writers state that in the act of spawning the female salmon digs with her flexed body and extrudes a few eggs, which are swept along with the displaced gravel. The male then takes her place and sheds his milt over the eggs. The alternate extrusion of eggs and milt continues with the digging of the female until a considerable heap of gravel has been formed. The female salmon rests in the pools between the periods of spawning activity and completes her task in from 7 to 10 days. Calderwood (2) states that the mound of gravel at the lower end of the hollow creates a cushion so that the water in the hollow into which the eggs are shed is not greatly affected by the current. When the female begins to shed her eggs, the attending male swims into the redd alongside the female and extrudes his milt, the eggs being fertilized on their way to or among the loose stones.

Our observations are at complete variance with the records of the older writers and differ somewhat from those of Calderwood. The actual spawning act has seldom been observed, since it rarely occurs during the daytime. As far as the writer knows, the fol-

lowing description is the only actual record of the natural spawning of the Atlantic salmon. It agrees closely with the description of the spawning of the trout as described by Greeley (3). Practically all previous descriptions have been confused with the digging of the redd, an operation entirely distinct from the spawning act.

A female salmon was observed to spawn once in seven hours of intermittent digging. The eggs were not shed at the time of the flexion of the body in digging but while the salmon was lying longitudinally in the current at the upper part of the hollow. The particular female salmon was accompanied by two males, the larger lying with its head 2 to 3 feet below the tail of the female and the smaller some 6 feet below the first male and several feet to the side. Three minutes after digging the female left the redd for 3 minutes. Two minutes after her return, as she lay extended at the upper part of the hollow, without warning marked activity was observed. The two males rushed quickly alongside, one on each side of the female. From outside the field of observation a third male came with a quick rush and lay along the side of another male, all four salmon crowding as close together as possible over the hollow bed, bodies parallel, heads on the same level and mouths wide open. The bodies of the males, which remained straight in the axis of the current, were slightly turned toward that of the female and were motionless except for fine muscular quivers. Suddenly the water became densely clouded with the milt shot from all three males, completely masking the depositing of eggs by the female. The entire procedure was accomplished within 10 seconds and the males then dropped back to their respective positions below the redd. Immediately the female manifested marked activity, digging frantically to cover the fertilized eggs. In the next 3 minutes she had 8 spells of digging, each time making from 5 to 8 muscular "flittings" of the body and tail. The act of spawning took place at 4:00 P. M. and no further spawning occurred during the next two hours.

It is impossible to state just what happened to attract the male salmon at the crucial moment. There was no particular movement of the female. Theoretically, some chemical stimulus may have attracted the first male, and its rush may have been the visual stimulus which drew the other two males from the greater distance. The opening of the mouth of the salmon during the spawning act holds the fish in position against the current during the discharge of the sexual elements. It is associated in some way with the muscular contractions by which the milt or eggs are extruded. Male salmon, when stripped, may open their mouths in the same manner.

Fertilization for the most part takes place before the eggs reach the bottom. The spermatozoa are immotile until they come in contact with the water, when they immediately take on frenzied

activity, which quickly diminishes until all movement ceases in about 45 seconds. Consequently, fertilization must take place during the first few seconds after the discharge. To be effective the milt should be discharged almost simultaneously with the eggs, since the current rapidly carries the milt downstream below the redd.

## Summary

1. The act of spawning of the Atlantic salmon is described.
2. Until ready to deposit ripe eggs, the female salmon may drive males from the redd.
3. The larger males usually occupy the position of favorite mate.
4. When there is an excess of males on the spawning grounds, changes in the role of favorite mate not infrequently occur.
5. With an excess of males the eggs of a single female salmon are often fertilized by more than one male, since, during the act of spawning, the favorite male is unable to chase off invaders.
6. The attractive force at the time of depositing the eggs extends to cruising males at a considerable distance.
7. The act of spawning is distinct from the operation of digging the redd.
8. The male is essentially the guardian of the redd and remains near the redd during the temporary absence of the female.
9. The spawning grounds are situated in the shallow swift water above or below the pools. Suitable grounds require a coarse gravel and stone bottom, a moderately swift current, a depth of water less than 4 feet, and often a protecting shore.
10. Rivers vary in the extent of suitable spawning grounds, depending upon their topographical features. The extent of the spawning grounds is one means of determining the productive capacity of a salmon river.

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## Discussion

Mr. Nobbs: I should like to ask Dr. Belding whether the hooked jaw of the male may be regarded as relating to spawning. I quite agree with him that male salmon tend to chase one another away by biting each other, because we have found male salmon with a good many scars on them. On the other hand it is very currently believed that this hook is a fighting weapon, possibly for chasing smaller fish away. Some light may be thrown on that by the behavior

of the landlocked salmon of Finland, which are by far the gamiest of all Salmonidae. They are about fifty per cent heavier for their length than Atlantic salmon, and they have this peculiarity, that the males on the spawning beds do actually fight. I have not seen that fighting taking place, but I have caught great numbers of these fish, and one never could get a substantial sized male that did not have scars on him. The scars are from the dorsal fin back towards the tail. I remember very well one hard fighting six pounder male I had which did not have a single scale from behind the dorsal fin in its proper place, and some of them seemed to be old scars. The Atlantic salmon has this hook, which develops as the fish becomes ripe for spawning. I am wondering if Dr. Belding can throw any light upon the question of this hook. As I have said, in the landlocked variety, which is probably a very old variety of salmon in Finland, fighting certainly does take place. You never find a scar on a male Atlantic salmon, while the male landlocked salmon may be heavily scarred, sometimes completely scarred.

Dr. Belding: I am unable to answer your question. It is a secondary sexual characteristic, and it develops at the same time as the elongation of the head. In both the female and the male salmon from June to October there is an increase in jaw length, or an increase in the length, we will say, from the eye to the snout of the head—very marked in the male; rather slight but still definite in the female, and with that occurs the formation of the hook. It probably is connected with the function of attack and defense in the male, but I have cited these observations merely to indicate we had never seen it used, because it did seem to be a rather cumbersome arm. But undoubtdly it is something developed of that type, and now is more or less, you might say, a secondary sexual characteristic. Whether that is associated with pituitary change or is directly due to the development of the reproductive organs and arises from the activities of the testicular hormone, I do not know; it would be an interesting problem for a physiologist interested in ductless glands. I do know a very surprising thing about it: if you take the percentage measurements of the head of the male salmon, we will say they will be sixteen in June and about twenty-one at spawning time. If that remained a permanent thing you would expect that in June the second spawning salmon would be pretty nearly twenty or twenty-one, but instead of that he is back to about eighteen. Yet if you take an X-ray of the head you can still find traces of that previous extension of the jaw found at the time of spawning. Of course that does not answer your question relative to fighting ability. I was talking with Dr. Greeley the other day, and he might tell you, if he were willing, about the jaw in rainbow trout and the driving away of the males in that species.

Dr. Greeley: In listening to these two papers on the salmon I have been struck by the very great similarity between the salmon and the rainbow. As Mr. Mottley said in an earlier paper, they seem to be quite closely related. Dr. Belding's observations on the spawning are almost exactly in accord with the observations I made on the rainbow, which differs from both the brook trout and the brown trout in that more than one male takes part in the actual spawning act; also that the mouths of the fish are widely opened as they spawn in a swift current.

As to combat, I do not know much about Atlantic salmon, but I would be very much surprised if the hooked jaw were not used in fighting. Fights in the rainbow are scarce; they are very difficult to observe. I spent about eight days continuously at the spawning grounds on the Little Manistee River, where there were a good many hundreds of fish present, and I saw only two or three good combats. But they were real fights, the male striking through the mid part of the body where the wide open-mouth with the upturned jaw would be very efficient in holding on. As Dr. Belding has said, most males get right out of the way of the male consorting with the female. If a smaller male comes up to where the big male is, immediately he puts the intruder right off and there is no combat. But when a male comes up who is the same size as the male on the redd, instead of chasing that male the rainbow holds his ground and lets the other male come up to him. The two fish display side by side, I should say about a foot apart, and they look each other right in the eye, partly open their mouths and spread their fins—it is a distinctive display. They may then leave the nest, swim upstream side by side, and then one of them will drop downstream, get a good run, and strike the other just as hard as he can amidships. The male attacked will accept that bite without any display of fear, and will in turn drop downstream to get a good run and attack the other fish in exactly the same way. I have seen two big rainbows, evenly matched, twenty-seven to thirty inches long, go downstream, one of them leaving the redd—they lose all instinct to keep guard on it under these circumstances—and attack each other in that way. You could see them splash, and while it was difficult to follow the fish and see everything that was going on or determine who won the battle, there was no doubt that it was a real fight, and the hooked jaw was used.

In relation to weight loss I have weighed only a few rainbows. I weighed only one small rainbow which was tagged and he had lost a little bit of weight in seven days. But I did see in watching the spawning grounds a good many fish which appeared to be very fresh and in good condition, but within four or five days they would get very thin. So that the weight loss in the rainbow does occur right at the time of spawning and apparently is correlated with great activity. The males are ceaselessly moving, chasing other males, and you can almost watch the flesh melt off them if you observe them closely for several days. The weight loss at that period is considerable and very rapid.

Mr. Russ (New York): I wish to corroborate what Dr. Greeley has said in regard to the aggressiveness of the rainbow male. I have seen them fight for an hour and a half to two hours—two males—and they will fight until one or the other is killed.

# THE CAUSE OF THE HIGH MORTALITY IN THE ATLANTIC SALMON AFTER SPAWNING

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The salmon has long been of interest to physiologists as an animal in which the development of the reproductive organs is associated with a prolonged fasting period. The Atlantic salmon enters the rivers of the Gulf of St. Lawrence from May to November, and in England and Scotland it arrives earlier, from January to October. Since spawning occurs in late October and early November, the pre-spawning residence in fresh water ranges from five to nine months for the early run fish, and in the case of the "winter" salmon, which enter the St. John River of New Brunswick in the previous November, the period is twelve months. During its fresh water stay the salmon takes no food, drawing upon its stored reserve for the energy expended in ascending the rivers and for the development of the sexual organs. Consequently, there is loss in weight, reduction of the stored fat, and changes in the composition of the muscles and viscera.

An indication of the changes in the condition of the salmon during its residence in fresh water is shown by the losses in weight which occur previous to, at the time of, and after, spawning. During its ocean life and previous to its spawning journey the salmon has prepared for its prolonged fast by accumulating a large store of fat in the body, particularly in the vicinity of the pyloric appendages. The great depletion of this fat during the pre-spawning period may be readily seen by comparing the viscera of salmon taken in May and in October. Not only is there a decrease of the reserve fat but also of the carbohydrates, fats, and proteins of the tissues, since the salmon differs from hibernating animals in expending energy in the ascent of rivers, in spawning activities, and in transforming material for the building up of the reproductive organs.

## Loss of Weight Previous to Spawning

Salmon enter the Miramichi River in New Brunswick from May to October, the heaviest runs occurring in June and October. After migration from the deep sea feeding grounds the late run salmon remain in the coastal waters off the eastern shores of New Brunswick, where many are taken with drift nets. Monthly observations upon the changes in weight of two-winter sea-life salmon of uniform size were made simultaneously in the river and in the

sea from May to October. Since most of the salmon were still feeding at their first appearance along the coast in May, the average weight for the month of May has been taken as the starting point. (Table 1.)

TABLE 1. PER CENT LOSS IN WEIGHT OF TWO-WINTER SEA-LIFE SALMON

| | Males | | Females | |
|---|---|---|---|---|
| Month | Ocean | River | Ocean | River |
| May | 0.0 | 0.0 | 0.0 | 0.0 |
| June | 1.9 | 4.3 | 1.8 | 2.7 |
| July | 6.8 | 8.6 | 5.4 | 6.4 |
| August | 11.7 | 12.9 | 9.0 | 10.1 |
| September | 16.6 | 17.2 | 12.6 | 13.8 |
| October | 21.5 | 21.5 | 16.2 | 17.5 |
| Number | 155 | 88 | 377 | 309 |

There was little difference in the loss of weight in the salmon entering the river and in those remaining in the sea, which would eventually enter the river in the following months. In June the salmon entering the river had ceased feeding several weeks earlier and had lost more in weight than those remaining in the sea, but this difference decreased as the time of spawning approached. After the middle of June there was a marked decline in the number feeding in salt water and no salmon were found after July 20th with food in their stomachs. Evidently earlier river ascension is associated with earlier cessation of feeding, more advanced development of the reproductive organs, and slightly greater loss of weight.

During the pre-spawning period the male salmon not only begins to lose weight earlier but loses 4.7 per cent more in body weight than the female because of a greater expenditure of energy. Actually the female loses a greater amount of fat, carbohydrates, and proteins from the muscles and viscera, which is compensated for in part by storage in the ovaries. The calculated loss of body weight exclusive of the reproductive organs is given in Table 2.

TABLE 2. PER CENT LOSS IN WEIGHT EXCLUSIVE OF REPRODUCTIVE ORGANS

| Month | Males | Females |
|---|---|---|
| May | 0.1 | 0.5 |
| June | 4.5 | 3.5 |
| July | 9.1 | 8.0 |
| August | 13.9 | 14.9 |
| September | 19.2 | 23.9 |
| October | 26.3 | 41.5 |

## Loss of Weight During Spawning

Records from the Canadian hatcheries show that the loss of weight in female salmon after stripping is 24.1 per cent, which corresponds closely to the percentage of the ovaries to total body weight. The weight of the testes at the time of spawning is approximately 5 per cent.

After spawning the salmon resides for a variable time in the river before passing back to the sea, either returning immediately after a short period of recuperation or remaining in the fresh water until the following spring. To a large extent the time of return to salt water depends upon the character and location of the river and the distance of the spawning grounds from the sea. Our knowledge of the post-spawning period is based upon the weights of recaptured kelts which were tagged at the time of spawning in the Canadian hatcheries. Recaptures in fresh water in May, previous to the resumption of feeding, give an additional loss of 19.7 per cent for the males and 11.5 per cent for the females. The greater loss by the male may be attributed to the fact that for some time after spawning it remains guarding the spawning grounds, while the female returns to rest in the quiet pools.

## Total Loss in Weight of the Spawning Salmon During River Life

Table 3 gives the total loss in weight of the salmon as calculated from the beginning of the spawning journey until it leaves the river in the spring as a kelt. The final loss is approximately the same for both the male and female salmon. The loss is greater in the male during the pre-spawning and post-spawning periods and greater in the female during spawning; for in the act of spawning the loss of weight from the reproductive organs is 3.9 per cent for the male and 20.0 per cent for the female. The greater part of the loss in the weight of the male, 38.4 per cent, is due to energy expended in ascending the river and on the spawning grounds. The female, on the other hand, consumed only 24.1 per cent of her weight in a similar manner. In the salmon which return to the ocean before January the total loss of weight is less and is approximately 31 per cent for the male and 39 per cent for the female.

TABLE 3. PER CENT LOSS IN WEIGHT DURING RIVER LIFE

| | Male | Female |
|---|---|---|
| Pre-spawning period | 21.5 | 16.8 |
| Spawning period | 25.4 | 36.8 |
| Post-spawning period | 42.3 | 44.1 |

## The Mortality of the Atlantic Salmon

Our data show that the percentage of Atlantic salmon which return from the sea to spawn a second time is surprisingly low, averaging less than 10 per cent and ranging from 3 to 26 per cent for Canadian rivers. Also the records of the Canadian Department of Fisheries show that there were only 2.12 per cent of recaptures among 6,475 salmon tagged after spawning. Whether

the salmon perish in the river after spawning, like their Pacific cousins, or in the sea is not definitely known, but, since dead salmon are seldom observed in the rivers, they probably perish in the ocean.

The foregoing statistics on the loss of weight furnish a logical explanation of this high mortality. Physiologists have found that death occurs in animals during starvation when the body weight is reduced approximately 40 per cent. Among the various figures given for animals are: man 40 per cent; dogs 31 per cent; guinea pigs 38 per cent; rabbits 40 per cent, and fowl 38 per cent. The loss of 31 to 44 per cent in weight according to the length of river life brings the salmon close to the line of physiologic death. As a result, it is so weak on its return to the ocean that it is unable to undergo normal recuperation, or it becomes the ready prey of its enemies. The second spawning salmon are recruited from the more vigorous individuals which manage to recover their strength before being subjected to a hostile environment.

The size of the river and the length of the journey to the spawning grounds appear to be factors in determining the percentage of surviving salmon. The additional energy expended by the Pacific species in their longer river journeys explains their complete destruction after spawning, whereas in the shorter rivers of eastern Canada a small percentage of Atlantic salmon manage to survive, though reduced to the borderline of existence. Although the early run salmon in the upper reaches have a more advanced development of the reproductive organs and a greater loss in body structure than the late run salmon in the lower part of the river, the difference in weight loss and distance travelled is too slight to differentiate the various rivers or parts of rivers in respect to the survival of salmon after spawning. The natural depletion of the body tissues to the borderline of death by physiologic starvation, the development of the sexual organs, and the expenditure of energy, are the real causes of the high mortality in the salmon after spawning.

## Discussion

Dr. Huntsman (New Brunswick): I should like to ask a question or two concerning two points in connection with the first paper presented by Dr. Belding. First, as to the loss in weight previous to spawning time, can he be certain that the fish are comparable during the different months from May to October? Is it not probable that there are successive lots of salmon coming in which would therefore not be strictly comparable? Second, with regard to the cause of the high mortality, has he been able, in the figures he gives as to percentages of mortality, to exclude causes of mortality which have no relation to the condition of the fish, as, for example, capture by man?

Dr. Belding: There is no way to exclude the arrival of fresh lots of salmon in the salt water during the period. Probably there is some augmenting of the salmon that are schooling along the coast in the seawater drift area at the mouth

of the Miramichi River between New Brunswick and Prince Edward Island. But it is impossible to exclude the arrival of new individuals, although I doubt whether it is very great. With respect to the reproductive organs, there is a difference between the salmon going up the river and those that are still in the salt water; in the case of the ones going up the river the eggs will be very slightly larger. The ovaries will weigh slightly more than in the case of salmon taken at the same time in the drift fishery, but the difference is surprisingly little. Undoubtedly those going up the river, particularly in June, have ceased feeding a little earlier than those that still remain—we get up to July 20 a certain number of salmon with food in their stomachs, and of course it is impossible to know what factor to multiply the per cent to determine the number of feeding salmon. It is possible that these salmon might represent new individuals arriving in the drift fishery; you absolutely cannot exclude the continuous arrival of new individuals into the coastal areas, but I doubt whether it comes to anything like fifty per cent.

As to the second question asked by Dr. Huntsman, relative to cause, you have to consider all types of causes brought in by man, the physical conditions of the river, the season, and so forth, as having their influence. I do not know that there is any explanation for the differences observed in that regard, unless it has something to do with the environment and the general condition of the river.

Mr. Rodd: In regard to the first paper, where were the salmon taken that you included as sea salmon?

Dr. Belding: All the pre-spawning records that I gave in the tables were taken from salmon entering the Miramichi river at Millerton, about ten miles above Newcastle, and naturally above the tidal water, and those were considered river salmon. The others were salmon that were taken in the drift nets off Escuminac between the north point of Prince Edward Island and the New Brunswick shore. I did not give the records from the Restigouche River, which are perhaps comparable, but I confined the catch to two year sea salmon in order to simplify the figures. I would say, however, that comparable results were found in the Restigouche River also.

Mr. Rodd: What months of the year were covered by the calculations included in the statement of spawning lots?

Dr. Belding: These figures were taken from the material that you gave me in regard to the records of your tagged salmon; they were drawn from the salmon that had been tagged after spawning at the hatchery and weighed and those that were caught in fresh water prior to May 15 when they more or less begin to feed. As to the other records, by plotting your total recaptures within that year you could find the recovery in weight in the mended kelt. I took only the fish that showed a sharply defined commencement of their mending, and the figures I gave include the fish before the beginning of the mending was sharply defined. The males did not lose nearly as much weight and did not recover nearly as much weight; the females lose a lot of weight and the recovery is correspondingly greater. Of course some individuals after they spawn commence to feed right away, and their recovery is much more rapid than that of fish which drift down the river and do not feed at once.

Dr. Huntsman: I suggest the possibility that the records might give some

facts to substantiate your theory with regard to the amount of loss determining survival, as to whether those that were recaptured coming up to spawn the second time were, from the records as to loss in weight, those that had lost least in the spawning at that time as compared with those that were not recaptured.

Dr. Belding: That would be very valuable, Dr. Huntsman, if we had it. Of course it could be done only indirectly, because we did not have the weights of the salmon in June, but only at the time of stripping. You could take the lengths and arrive at an average theoretical weight back in June—in other words, the so-called condition factor—and make a theoretical calculation as to the loss of weight on these fish, but you would have to have fairly large numbers to do that, many more than the actual number of tagged salmon that have been recaptured. I recall only about 2.12 per cent of the six thousand and some odd salmon having been recaptured—is that right, Mr. Rodd?

Mr. Rodd: That is about right. Could you compare the percentage of second spawners in the recaptures with the whole bulk of the scales examined with a view to seeing whether the fish we were catching had a larger number of second spawners than the salmon taken in the commercial catch?

Dr. Belding: The only way I can give a guess at that is that I think the percentage of recaptures of tagged salmon in Scotland was 2.1; therefore if you multiply that by five you get roughly about ten per cent, and that is just a trifle higher than the average for our rivers in second spawning salmon.

Mr. Jorgensen: I would like to ask if any experiments have been made in keeping salmon in captivity after spawning to see what happens to them, and to see how often they will spawn again?

Dr. Belding: There are records of their having been kept in fresh water, but those I have in mind have all been in Scotland. Mr. Rodd may have made some observations on that.

Mr. Rodd: We have not endeavored to keep them after stripping.

Mr. Jorgensen: In Denmark about six years ago two salmon, a male and a female, were caught by commercial fishermen, and a commercial hatchery man nearby got hold of these two salmon, stripped them, fertilized the eggs, getting three thousand eggs, and they all hatched out. He kept the two salmon and they spawned at least three years in succession. Right now they are taking eggs from the grandchildren of this original pair, and the Danish fishery department are getting a whole supply of Atlantic salmon eggs from these fish.

Mr. M'Gonigle: There is another case of tagged salmon which I think would be of interest in this connection. In the landlocked group, which do not have to make the long journeys of which Dr. Belding spoke, we have had very considerably more than a ten per cent return for second or even third spawnings.

# SPRING-RUN AND FALL-RUN ATLANTIC SALMON

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Among the many unsolved problems in the life history of the Atlantic salmon one of the most interesting is concerned with the time at which the salmon enter the rivers for spawning. In some rivers the majority of the salmon enter in the spring and a smaller number arrive during the summer and fall; in other rivers there is a more equal distribution of early and late-run fish; and in still others there are only late-run or fall salmon. Strangest of all are the so-called "winter" salmon which enter fresh water one year previous to spawning.

In eastern Canada only the early-run salmon of May, June and July are of real commercial value to the trap and drift fishermen. In September and October the poor condition of the salmon, irrespective of whether they are taken in the sea or in the river, renders them unsuitable for the market. In most of the rivers of the Maritime Provinces the best salmon angling is found in June when the spring run is at its height. At this time the water is cool, and the prime condition of the salmon which have recently entered the river gives superior fighting qualities. Except in a few rivers, a relatively small percentage of the rod catch is taken after the first of August. Consequently, Canadian rivers which have a limited spring run or an exclusively fall run are of little value either to the commercial river trap fishermen or to the anglers, bring no revenue from the leasing of fishing privileges, afford no employment for guides, and furnish no incidental revenue from sport fishermen. If the time of the main run in these fall-run rivers could be changed to the spring, they would become a valuable economic asset to the local communities and would increase the all too limited territory now available for salmon angling.

*Salmon Races:* The possibility that the early-run and late-run salmon are distinct races or varieties furnishes the simplest explanation of the differences in the river maturity, but it involves the supposition that each race will produce offspring of similar habits. Few subjects have called forth such a diversity of opinion among commercial fishermen, anglers, fish culturists, and fishery investigators. Calderwood (1), who is a firm advocate of the theory that spring-run and fall-run salmon are distinct races, has set forth evidence of considerable weight to support this viewpoint. On the other hand, Canadian fish culturists

and many fishery investigators contend that the offspring of late-running salmon return both as early and as late-run fish. This problem, if ever it can be solved, cannot be settled until carefully planned experiments have been conducted over a period of years.

Exact knowledge on this point would be of extreme importance in the conservation of the future salmon fishery of eastern Canada. It would permit the proper regulation of the commercial net fishery by the establishment of suitable closed seasons, which would prevent an excessive drain upon any special class of salmon and would indicate the proper source of the eggs for the salmon hatcheries. A critical analysis of the evidence at present available on this subject, although inconclusive, may help to clarify the situation and provide a working basis until extensive experiments and observations have definitely settled the question.

## Evidence for Separate Races of Salmon

If according to the parent stream theory there are distinct river races or varieties of salmon, it is not inconceivable that tributary streams or even sections of a river may produce still further subvarieties, since the parr tend to remain segregated in the localities where they are hatched. As a rule the late-run salmon chiefly occupy the spawning grounds in the lower reaches of the river and the early-run salmon more often frequent the upper waters. If river location through the effect of environment upon the parr in any way influences the future habits of the adult salmon, it will tend to establish distinct varieties which have an hereditary tendency to occupy the same spawning grounds.

Calderwood, who has observed the changes in the salmon run of certain Scottish rivers over a period of years, has found that regulation of the early net fishing has caused a general increase in spring-run fish along the coast of Scotland. The Tweed, which was a late-run river previous to the legal restriction of net fishing for early-run salmon, has changed to a spring-run river because the spring-run fish were protected. During the past thirty years the number of grilse in Scotland has decreased, while the number of spring-run salmon has increased. This phenomenon may be explained by the fact that grilse or late-run salmon beget offspring with late-run habits, and that the excessive late season netting during this period has reduced their numbers, and correspondingly the restriction of the early season netting through protection has allowed an increase in spring-run fish. He considers that unless there are periodic fluctuations in the proportion of early and late-run salmon, these changes present fair presumptive evidence of seperate races.

Grilse first enter the Scottish rivers in the early summer, are most numerous in July, and continue to enter until the spawning season. Recaptures of tagged grilse indicate that, if they return as adult salmon for a second spawning, they retain the late-run habit of entering

the rivers in the summer and autumn, while second spawning two or three-winter sea-life salmon maintain the early-run habit of entering in the spring. On this basis Calderwood assumes that the time of run is an hereditary characteristic. Our observations on the grilse of the Miramichi river, which also have the same late-run habit, do not corroborate these findings for Canadian waters. Scale readings show the presence of an appreciable number of second spawning salmon which first spawned as grilse in the early run of Miramichi salmon.

The results of salmon marking in the Chinook salmon on the Pacific coast furnish the most important evidence for racial differences between early and late-run salmon. The young Chinook salmon in the Columbia river migrate in two stages: the young of the "spring" salmon when one year old, and those of the "fall" salmon at the end of the alevin stage. The offspring of spring-run fish which were marked by Rich and Holmes (2), although reared in a locality occupied by fall-run fish, returned as adults to the locality, where they were reared, as spring-run salmon. Fry from fall-run salmon, which were reared in a locality which had naturally a spring run, returned as fall-run fish.

These experiments demonstrate beyond any reasonable doubt that these two classes of Chinook salmon reproduce salmon of similar habits. The offspring of the spring-run salmon which spawn in the upper waters differ so decidedly in their length of river life from the offspring of the fall-run fish of the lower part of the river that there is little question that they constitute two distinct varieties. The question naturally arises as to whether the results with the Chinook salmon can be applied to the Atlantic salmon, especially since the rivers of eastern Canada are relatively short, show little change in environment and present but slight differences in the life of the parr. However, by analogy it would suggest differences in the early-run and late-run Atlantic salmon.

## Evidence Against Separate Races

The evidence against separate races of early-run and late-run salmon in Canadian rivers is even stronger than the evidence in favor. It would seem that the differences which may exist between the two runs are so slight that the offspring do not consistently breed true to type.

Fall-run salmon which have been tagged when spawning by the Canadian Department of Fisheries have been recaptured in the spring and summer when they returned to spawn a second time. However, second spawning salmon cannot logically be likened to maiden salmon, and their habits may be entirely different.

Observations by Belding, Pender and Rodd (3) upon the time of hatching, length of incubation of the egg, duration of yolk sac stage, and early growth of the fry show no difference in the offspring of early and late-run salmon reared in the same environment, although differences between the salmon of various rivers can be shown in the

size of the egg, in the time of spawning, length of incubation period, and early growth of the parr.

Both the early-run and late-run salmon arrive about the same time on the eastern coast of Canada. Whereas the early-run salmon enter the rivers soon after arrival, the late-run fish remain in the coastal waters until the time of spawning. Only minor differences in feeding, development of the reproductive organs, and loss of body weight are found in these two classes. Statistical studies by Phelps and Belding (4) on the salmon of the Restigouche river indicate that there is but one race of salmon and that there is no evidence of any distinction between early and late-run salmon. These results are inconclusive, since the Restigouche river is preeminently an early-run river and has a relatively small number of late-run salmon.

The most important evidence in favor of a single race of salmon is found in the Miramichi river, New Brunswick, which has heavy runs of both early-run and late-run salmon. It has suffered for many years from excessive net fishing of the spring run with the result that relatively few salmon reach the upper waters in June and July. Most of the spawning salmon enter after the netting season in September and October. Nevertheless, each year there is a heavy spring run of considerable commercial value which is more extensive than the fall run. If fall-run salmon bred true to type, there would be practically no spring-run salmon entering the river. Yet in spite of the almost complete extermination of early-run spawning salmon, the supply of spring-run fish has been maintained. The only source of these early-run fish must be the fall-run salmon, unless the few spring-run salmon which escape the nets and anglers are able to produce an incredible number of offspring.

For the present the question of distinct races of early-run and late-run salmon must be considered open. All evidence on this point for the Atlantic salmon of the rivers of eastern Canada is either inconclusive or supports the contention that there is but a single race. Therefore, until further positive evidence is forthcoming there is no logical reason for considering spring-run and fall-run salmon as distinct races.

## Early-Run and Late-Run Salmon Rivers

The time of the main run of Atlantic salmon differs widely in the various rivers of eastern Canada. The rivers of the Bay of Chaleur and Gaspé peninsula with the exception of the Nipiscuit river and the smaller rivers in the neighborhood of Bathurst have usually an early run. The rivers of the North Shore of the St. Lawrence have a slightly later run than the Bay of Chaleur rivers, but essentially are early-run rivers. The Miramichi river has both early and late runs of salmon, but the small rivers of the eastern coast of New Brunswick, the Nova Scotia rivers of the Northumberland Straits, and the rivers of Prince Edward Island have only fall runs. A consideration of certain features of these rivers and of the salmon which remain until fall

in the coastal waters off the New Brunswick coast reveals certain factors which in part explain the differences in the time of run.

*Size of River:* The rivers which have exclusively fall runs are all small rivers, and the spawning grounds are situated relatively short distances from the mouths. The Miramichi river is the only large river with a fall run, but it also has a heavy spring run.

*Flow of water:* It is generally recognized that the attraction to and the progress of the salmon up the rivers is governed by the stimulating effects of the flow of fresh water, particularly during a sudden rise. The volume of water in the small rivers decreases rapidly in the early summer and remains low until fall. Unless the salmon enter in the very early spring, the volume of flow is not sufficient to attract or even permit them to ascend. A striking example as to the influence of water flow upon the time of run of the salmon occurred in 1930. The fall run entered the small rivers of the New Brunswick coast in the last of September and was practically over by the first of October. Owing to abundant rainfall in the late summer and early fall on the New Brunswick coast these rivers had a good flow of water. Only a short distance to the south on the Northumberland Straits shore of Nova Scotia, where there had been no rainfall for a long period, the rivers were low. By October first no salmon had entered either of the two principal rivers, the Philip and the Wallace, and the customary run did not occur until later when the flow of water had been augmented by rains.

*Temperature:* Calderwood (5) has clearly demonstrated that the temperature of the water, both actual and relative, does not attract salmon from the sea to the rivers. Apparently it has little influence in the rivers of eastern Canada, although the higher water temperatures of the summer may be less favorable to the salmon than the lower temperatures of the spring and fall. In the Margaree river of Cape Breton, the high temperature of the Southwest Margaree is apparently the factor which limits the run in this branch to early spring and late fall, whereas the colder waters of the Northeast Margaree permit a continuous run from spring to fall.

*Salmon:* The possibility that minor differences in the salmon may affect the time of run must be considered. The development of the sexual organs in the salmon entering the rivers in the spring is slightly more advanced than in the salmon which remain in the sea to enter the rivers later. Cessation of feeding bears some relation to the time of river maturity. The early-run salmon which enter the river have ceased feeding, whereas in June and July a small percentage of those in the coastal waters are still feeding. Measurements of salmon entering the Miramichi river showed practically no difference in length between early-run and late-run fish, in spite of the longer sojourn and longer feeding period of the latter in salt water, indicating that the larger or more advanced salmon tended to enter the river earlier.

These facts indicate that early river maturity is associated with

precocity or accelerated development on the part of the salmon. Those salmon which have ceased feeding early, which have sexual development above the average, and which have reached the standard size for that year are the ones which show an early river maturity. Whether this accelerated development is due to heredity or whether it is largely controlled by environment during the river life of the parr and the later sea life of the salmon is impossible to state. If it is the result of the former, it favors the idea of separate races of early and late-run salmon. If it is due to the latter, it indicates that there is no racial difference and that the offspring of both runs may become either spring- run or fall-run fish.

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# GROWTH OF THE WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL), IN TROUT LAKE, NORTHEASTERN HIGHLANDS, WISCONSIN

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This study of the growth of the whitefish is based on a small number of specimens taken incidentally in the collection of materials for the investigation of the life history of the lake herring or cisco (*Leucichthys artedi*) in Trout Lake, Wisconsin. Although the available data offer no basis for any detailed analysis of the growth of the whitefish in Trout Lake, they give a satisfactorily reliable general growth curve for this exceptionally slow growing population.

Trout Lake, the location of the limnological laboratories of the Wisconsin Geological and Natural History Survey, is situated in Vilas County in the heart of the lake district of northeastern Wisconsin. According to Juday and Birge (1930) Trout Lake has an area of 1,683 hectares (4,160 acres), a depth of 35.0 meter (115 feet), and lies at an elevation of 493 meters (1,618 feet) above sea level. It is the deepest and next to the largest of the lakes of the northeastern highlands region. Data (made available through the courtesy of Dr. Chancey Juday of the Wisconsin Geological and Natural History Survey) concerning the south basin, in which all whitefish samples were taken, are: total volume, 149,020 thousand cubic meters; Secchi disc transparency, 4.5 meters; color, 3 (platinum cobalt scale); pH, 7.6; conductivity in reciprocal megohms, 77; bound $CO_2$ in milligrams per litre, 18.7; organic matter of plankton in milligrams per litre 0.92. The data concerning the physical-chemical nature of the water, and the abundance of organic matter of plankton, represent average surface conditions.

In middle and late summer, the time of year in which the samples were collected, the whitefish of Trout Lake lives in the hypolimnion where it finds not only water of suitable temperature but also an abundance of disssolved oxygen (Juday and Birge, 1932). In the same strata inhabited by the whitefish are to be found a very dense population of the cisco (*Leucichthys artedi*), considerable numbers of lake trout (*Cristivomer namaycush*) and a few burbot (*Lota maculosa*). There is probably considerable competition for food between the whitefish and the cisco.

The whitefish collections consist of seventeen fish taken in 1927, two

in 1928, nineteen in 1931 and thirty in 1932. All specimens were taken in gill nets. There are no individual net records for 1927 and 1928, but in 1931 and 1932 whitefish were taken in the following sizes of mesh (stretched measure, in inches): 1¼, 1½, 1¾, 2, 2¼, 2½, and 3. Scale samples, taken from the left side of the body from the area between the lateral line and the base of the dorsal fin, were stored in Bureau of Fisheries scale envelopes. In 1931 and 1932 the data recorded on each envelope included date, standard length in millimeters (total length for a few individuals),[1] weight in grams, sex, state of maturity, and size of mesh in which the fish was taken. The 1927 and 1928 data included only the date and the standard length in millimeters.

In the laboratory three scales, selected on the basis of clearness of sculpturing and symmetry of form, from each fish were mounted on a glass microscope slide in a glycerin-gelatin medium made according to the formula given by Van Oosten (1929). The scales were examined by means of the microprojection apparatus described by Van Oosten (1923). The magnification used was X40.5.

Ages were determined by counting the number of annuli (year-marks) or lines of discontinuity between the growth areas of successive years of life. One of the three scales on each slide was measured. For this purpose a tested millimeter ruler was placed upon the projected image along the antero-posterior axis and the diameters of the successive growth areas determined to the nearest millimeter. The calculation of the growth history of the individual fish was based on the assumption that the ratio of scale diameter to body length is constant at all lengths beyond that at which the first annulus is laid down. Van Oosten (1923) demonstrated that this assumption gives highly reliable results in the calculation of the growth of the whitefish. In the same paper on the basis of the examination of the scales of whitefish of known age, Van Oosten proved that in this species the annulus can be taken as a true year mark.

In spite of the slow growth of the Trout Lake whitefish and the advanced age of the specimens in the collection, little difficulty was encountered in the interpretation of the scale structures. Of the 68 fish studied only one was discarded as having scales wholly unsuited for the determination of age. The age determinations of three other fish were indicated as possibly a single year in error.

Table 1 shows the results of the age determinations and growth calculations. In the preparation of the table corresponding age groups of the different years' collections were combined. The ages designate the number of annuli present, or the number of completed years of life. Although the whitefish spawns in late autumn it is considered that the life of the individual begins at the time of hatching the following spring. Thus a fish in its first summer has no annulus and is a member of the O-group; in its second summer it has one annulus and is a member of the I-group, etc.

[1]The ratio, total length in standard length is 0.835 for the Trout Lake whitefish.

TABLE 1. AVERAGE LENGTH IN MILLIMETERS AT TIME OF CAPTURE AND CALCULATED LENGTH AT THE END OF EACH YEAR OF LIFE OF EACH AGE GROUP OF THE TROUT LAKE WHITEFISH (CORRESPONDING AGES OF ALL COLLECTIONS COMBINED). BELOW, GRAND AVERAGE OF THE CALCULATED LENGTHS AT THE END OF EACH YEAR OF LIFE AND ANNUAL CALCULATED GROWTH INCREMENTS. AGE GROUPS MARKED WITH ASTERISKS WERE NOT EMPLOYED IN THE CALCULATION OF THE GRAND AVERAGE.

| Age | Number of specimens | Length in millimeters | Calculated length in millimeters at the end of each year of life | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| XIV | 2 | 374 | 70 | 113 | 144 | 182 | 210 | 232 | 256 | 278 | 297 | 318 | 330 | 342 | 357 | 366 |
| XI | 1 | 348 | 94 | 118 | 165 | 193 | 220 | 255 | 268 | 288 | 307 | 322 | 338 | ...... | ...... | ...... |
| IX | 3 | 314 | 71 | 104 | 142 | 173 | 198 | 229 | 253 | 280 | 306 | ...... | ...... | ...... | ...... | ...... |
| VIII | 4 | 277 | 80 | 113 | 135 | 162 | 193 | 211 | 241 | 267 | ...... | ...... | ...... | ...... | ...... | ...... |
| VII | 7 | 264 | 82 | 114 | 150 | 181 | 209 | 232 | 251 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| VI | 17 | 246 | 82 | 120 | 153 | 182 | 209 | 232 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| V | 9 | 224 | 80 | 116 | 150 | 183 | 208 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| IV | 12 | 204 | 83 | 120 | 155 | 185 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| *III | 6 | 180 | 95 | 130 | 166 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| *II | 3 | 195 | 96 | 156 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| *I | 3 | 130 | 93 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| | 67 | Grand average | 81 | 117 | 151 | 181 | 207 | 230 | 251 | 275 | 303 | 319 | 333 | 342 | 357 | 366 |
| | $\Delta$ | $\Delta L$ | 81 | 36 | 34 | 30 | 26 | 23 | 21 | 24 | 28 | 16 | 14 | 9 | 15 | 9 |

The data of Table 1 show a very close agreement among the calculated growths of the best represented age groups (IV to VII, inclusive). The older, poorly represented age groups show certain irregularities but in general agree well with age-groups IV to VII. The calculated growths for the three youngest age groups, particularly I and II, tend definitely to be higher than those based on fish of greater age. These high calculated growths of the younger age groups are probably the result of selection by the gear used in collecting the samples. Such a conclusion is supported by the observation that the first three age-groups are poorly represented in the samples, whereas they would be expected to outnumber fish of greater age.

At the bottom of Table 1 may be found the data for the general growth of the Trout Lake whitefish, based on a combination of all specimens older than the III-group. (See also Figure 1). The data given include the average calculated length at the end of each year of life and the calculated increment of growth during each year of life. The data show that the first year's growth is more than twice as great as that in any other year of life. The annual increments of growth decrease continuously during the first seven years. The small number

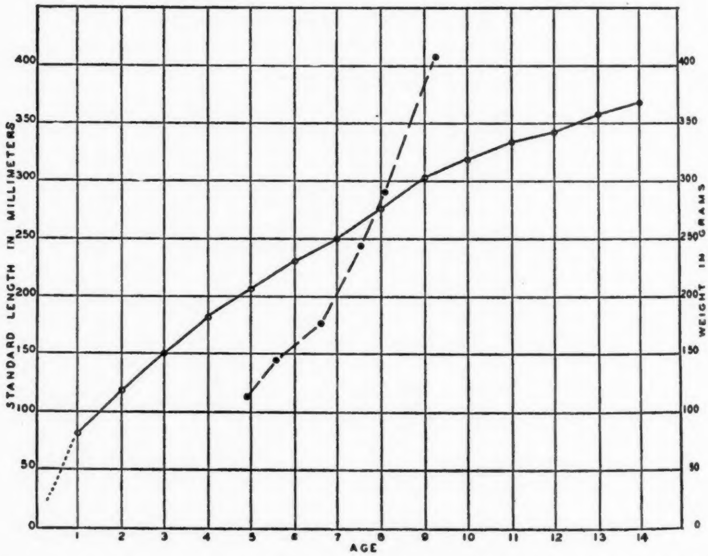


**Figure 1.**—Average calculated length (in millimeters) of the Trout Lake whitefish at the end of each year of life o—o—o, and average weight (in grams) of the various age groups o - - o - - o.

of specimens in the age groups above the VII-group causes the later portion of the curve for growth in length to be irregular.

Data on the growth in weight of the Trout Lake whitefish appear in Table 2. (See also Figure 1). Here again, the data for the first three age groups must be considered unreliable because of selection by gear. The data of Table 2 do not include the 1927 and 1928 collections for which no weights are available. Along with the weight data are presented the values of the coefficient of condition, the quantity, K, in the equation $W = K \times 10^{-5} L^3$, where $W$ = weight in grams and $L$ = (standard) length in millimeters. It may be seen that although the greatest amount of growth in length occurs in the first year of life, the largest annual increments of growth in weight are found in the later years of life. The values of K show that while the older fish may have a slightly heavier build than the very young ones, there is on the whole little change in the relative heaviness of form with continued growth.

TABLE 2. LENGTH (IN MILLIMETERS), WEIGHT (IN GRAMS), AND CONDITION (K) OF THE DIFFERENT AGE-GROUPS OF THE TROUT LAKE WHITEFISH, BASED ON THE COMBINATION OF THE 1931 AND 1932 COLLECTIONS.

| Age group | I | II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|---|
| Number of fish | 3 | 1 | 2 | 11 | 8 | 12 | 6 | 4 | 1 |
| Standard length | 130 | 164 | 179 | 204 | 220 | 242 | 263 | 277 | 307 |
| Weight (grams) | 25 | 55 | 81 | 113 | 144 | 177 | 244 | 290 | 408 |
| $\Delta$ W | 25 | 30 | 26 | 32 | 31 | 33 | 67 | 46 | 118 |
| K | 1.14 | 1.25 | 1.39 | 1.31 | 1.35 | 1.25 | 1.34 | 1.36 | 1.41 |

The relative abundance of the sexes in the samples was in the ratio of 162 females per 100 males. The data were inadequate for any study of the relationship between the sex ratio and age. It is probable that none of the fish reach sexual maturity before the end of the fifth or sixth year of life.

The slow growth of the Trout Lake whitefish is brought out sharply by a comparison with the growth of whitefish populations in other localities. Table 3 compares the growth in length of the Trout Lake whitefish with that of the whitefish in Lakes Winnipeg and Winnipegosis (Bajkov, 1930); Shakespeare Island Lake, Lake Nipigon, and Lake Ontario (Hart, 1931); and Hudson Bay (Dymond, 1933). Table 4 shows a comparison of growth in weight for the same populations, with the exception of Hudson Bay. The methods of the various authors of expressing age and weight have been modified, where necessary, to conform with the method used in this study. In order to make the Trout Lake data on growth in length more comparable with those of other workers the average lengths of the different age groups at the time of capture have been used rather than calculated lengths at the end of completed years of life. It may be seen at once that the Trout Lake whitefish has the slowest growth of any of the seven populations. The slow growth in the Trout Lake stock is particularly striking with respect to growth in weight. This slow growth in weight

may depend in part on slenderness of form as well as on the slowness of the growth in length.

TABLE 3. COMPARISON OF THE AVERAGE LENGTHS (IN MILLIMETERS) OF THE DIFFERENT AGE GROUPS OF THE TROUT LAKE WHITEFISH WITH THE AVERAGE LENGTHS OF FISH OF CORRESPONDING AGE IN OTHER WHITEFISH POPULATIONS

| | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV |
| Trout | 204 | 224 | 246 | 264 | 277 | 314 | ----- | 348 | ----- | ----- | 374 |
| Hudson Bay | 241 | 260 | 273 | 318 | 358 | 367 | ----- | ----- | ----- | ----- | ----- |
| Ontario (Pleasant Point) | 336 | 346 | 409 | 459 | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Nipigon | 227 | 238 | 251 | 282 | 322 | 358 | 384 | 393 | 400 | 404 | 435 |
| Shakespeare Island | 231 | 241 | 259 | 286 | 302 | 316 | 348 | 364 | 370 | 371 | 396 |
| Winnipeg | 380 | 420 | 450 | 480 | 500 | 520 | 540 | 560 | 575 | 585 | 590 |
| Winnipegosis | 390 | 420 | 450 | 480 | 500 | 520 | 540 | 560 | 575 | 585 | 592 |

TABLE 4. COMPARISON OF THE AVERAGE WEIGHTS (IN GRAMS) OF THE DIFFERENT AGE GROUPS OF THE TROUT LAKE WHITEFISH WITH THE AVERAGE WEIGHTS OF FISH OF CORRESPONDING AGE IN OTHER WHITEFISH POPULATIONS

| | Age | | | | | |
|---|---|---|---|---|---|---|
| Lake | IV | V | VI | VII | VIII | IX |
| Trout | 113 | 144 | 177 | 244 | 290 | 408 |
| Ontario (Pleasant Point) | 540 | 790 | 1,130 | 1,500 | ----- | ----- |
| Nipigon | 140 | 230 | 280 | 400 | 570 | 850 |
| Shakespeare Island | 190 | 220 | 280 | 400 | 450 | 540 |
| Winnipeg | 772 | 1,044 | 1,135 | 1,362 | 1,498 | 1,680 |
| Winnipegosis | 817 | 1,044 | 1,135 | 1,362 | 1,498 | 1,680 |

The great density of the fish population of Trout Lake in the strata inhabited by the whitefish appears to offer the most logical explanation of the slow growth of the whitefish in that body of water. Although whitefish are not particularly abundant in Trout Lake, they occur along with an extremely dense population of small, slow growing lake herring or ciscoes.[2] Whether the crowding impedes growth through the creation of intense competition for food or through the operation of a "space-factor," whereby crowding hinders growth independently of competition for food, remains to be demonstrated.

## Summary

The whitefish of Trout Lake, northeastern Wisconsin, shows the slowest growth yet recorded for any North American population of that species. This slow growth is probably the result of the great density of the fish population, particularly of the lake herring, in the hypolimnion of the lake. The crowding may impede growth through the creation of intense competition for food or through the operation of a "space-factor."

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# QUANTITATIVE STUDIES OF STREAM BOTTOM FOODS

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In relation to stocking policies, the amounts of food found in both streams and lakes, is of permanent importance. Most stream studies made both by ecologists and entomologists in the past have been qualitative rather than quantitative in nature and have largely related to the distribution of individual genera or species of aquatic organisms. Measurements of the total food supplies, their seasonal abundance, rate of increase, and actual availability to trout have for the most part not been determined.

The main underlying reason for the lack of quantitative measurements of stream foods to date has been the difficulty in devising appropriate apparatus that would permit easy collection of accurate samples from rocky or gravelly stream beds. Further, streams offer far less stable year-round conditions than lakes and the difficulties of seasonal work are therefore increased many fold. Lake studies have proceeded apace, first, because of their more stable conditions, and second, because of the development of suitable tools for collection of samples such as the Peterson and Ekman dredges, Kemmerer water bottle, the various plankton nets and pumps now widely used.

## Method of Taking Samples

The writer in 1927, while working on the New York Biological Survey, devised the "square-foot" box for taking quantitative stream foods samples from an area of one square foot. This consists merely of a galvanized iron box, 26 inches deep, open at both ends, exactly one foot square inside measurements. The upper edges are rolled over a heavy gauge rod and the lower edges strengthened by riveting a piece of band iron flush with the bottom all around. This edge is the one pushed into the stream bed and must be strong enough to withstand rough use when pushed into gravel or rubble bottoms.

In taking a sample, the box is merely pushed into the stream bed and the organisms enclosed within the area are removed by means of sieves. This simple piece of apparatus works well in water up to two feet in depth and where the bottom materials are sufficiently small to permit setting the box properly. In streams

NOTE:—The writer wishes to thank Mr. Francis Sumner and Mr. Leo Shapovalov for their assistance in various phases of this work.

having bottoms of large boulders and rubble it cannot be used. Under such conditions about the only quantitative method possible is to make hand counts from stones offering measurable surface areas as done by Needham (J. G., 1927) in the streams of Utah.

When using the square foot box a 30 mesh handscreen is always held about the lower edges of the box on the downstream side to prevent loss of organisms due to irregularities of the bottom.

In rubble bottoms in swift water, it is impossible to prevent some loss of organisms in taking the sample. Back washes from the current, even with the box edges pushed as far as possible into the substratum, cause some losses. However one would expect the error due to roughness in securing the samples to be about constant in any given type of bottom. On the other hand, in gravel riffles composed largely of small stones, the box can often be pushed quickly from three to six inches into the bottom and quite accurate samples be obtained.

Once the box is securely in the bottom, with the handscreen in place, the larger stones enclosed are lifted out and the organisms washed off into a bucket. The bottom is then stirred up using a shallow 30 mesh sieve. The organisms are washed off the sieve into a bucket and this process is continued until no more can be obtained. Any swept out of the box onto the handscreen are also dumped into the bucket and taken as part of the sample.

The food elements and trash in the bucket are now washed of mud and silt by pouring the sample through a 30 mesh soil sieve. The catch is then washed off the sieve into a quart fruit jar and brought indoors. While still alive, food organisms are separated from trash. After being sorted into a white enamel pan, the organisms are poured into a fine mesh tea strainer and held on blotting paper for one minute to remove excess moisture. The total catch is then weighed on torsion balance scales.

The weight thus obtained is the wet weight (w.w.) in grams of the total bottom foods obtained from any given area. The figures submitted here giving pounds of food per acre are naturally based upon recalculations from averages of these figures.

The bottom foods studies, the results of which are given here, were begun in New York and have been continued in California since 1932 as a major part of the field program of the California Trout Investigations.*

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*These investigations were actively started in 1932 as a cooperative project between the U. S. Bureau of Fisheries and the California Division of Fish and Game. The personnel consists of Mr. A. C. Taft and the writer from the U. S. Bureau of Fisheries and Mr. Leo Shapovalov and Mr. Francis Sumner supplied to the work by the State.

**TABLE 1. WET WEIGHT OF FOOD ORGANISMS IN GRAMS PER SQUARE FOOT FOUND IN STREAMS OF VARYING WIDTH GROUPS***

| Width of Stream in Feet | Number of Samples | Wet Weight of Food Per Square Foot | Pounds Per Acre |
|---|---|---|---|
| 1-6 | 10 | 2.06 | 197 |
| 7-12 | 26 | 1.67 | 160 |
| 13-18 | 24 | 0.94 | 90 |
| 19-24 | 9 | 0.51 | 48 |
| 25-30 | 6 | 0.62 | 59 |
| 30-50 | 9 | 0.67 | 64 |
| 50-100 | 21 | 0.69 | 66 |
| | 105 total | 1.02 average | 97 average |

*Based on studies made on the New York Biological Survey in 1927-28. The data submitted in this table are the writer's for streams up to 50 feet in width. The figures submitted for 50-100 ft. streams are taken from work by Pate (1931) done in the Oswegatchie and Black River systems in New York. Later work by Pate in streams of the upper Hudson watershed has shown more than twice the amount of food in streams of this region in the 50-100 ft. group. I am using Pate's 1931 findings as being most consistent with my own.

## Distribution of Foods in Relation to Stream Width

Léger (1910), from work done on the biogenetic capacity of streams near Grenoble, France, stated that the food elements decreased by one-half from the shoreline to the middle of the channel in streams above five meters (16.4 ft.) in width. Subsequent work by Needham (1928) and by Pate (1931) showed this not to be true. These workers, in streams above 18 ft. in width,* found decreases from shorelines to mid-channels of 11.05 per cent and 16.66 per cent respectively. These results were obtained in trout waters near Ithaca, N. Y., and in the Oswegatchie and Black River systems in northern New York.

However, later work by Pate (1932) in the streams of the upper Hudson drainage in New York confirmed Léger's findings, where he obtained a decrease of 53 per cent. Much further work will be necessary on this feature of the distribution of aquatic fish foods. It has become quite evident from the writer's observations that what is true for one drainage area does not by any means hold true for any other. Each presents its own environmental peculiarities and must be studied individually in relation to the stocking program.

By averaging our sample weights from streams of varying width groups regardless of whether they had been taken at sides or centers of streams, several significant facts are indicated. This has been done in Table 1, where it is shown that narrow streams belonging to the 1-6 ft. group averaged over 2.06 grams per square foot while those in the 19-24 ft. group averaged only 0.51 grams of food per square foot. It is also to be noted that there is a steady decline in the amounts of food found from streams of the 1-6 ft. group to those belonging to the 19-24 ft. group. Beyond

*The division of streams into two groups, those above, and those below 18 ft. in width was not done arbitrarily. Previous work showed this to be the stream width at which the nutritive elements were most evenly scattered over the bed, more food being found in the centers of streams narrower than this, and less being found in the centers of those wider than this.

this point in the wider streams, the rise is slight to the last or 50-100 ft. group.

While the data submitted in Table 1 are based upon only 105 samples, nevertheless they indicate clearly the tremendous amounts of food that are available in the smaller spring-fed tributaries less than twelve feet wide. Had more data been obtained on the amounts of food in streams above 18 feet in width, doubtless the averages for the wider width groups would show even less variation than is shown in this table.

The average wet weight of food found in the samples listed in Table 1 was 1.02 grams per square foot or 97 lbs. per acre of riffle area. No pool sample determinations are included in this table. This general average agrees closely with that of Pate (1932) for all streams regardless of width.

While it may superficially appear that more foods may be present in the small streams, a few simple calculations will show, when total bottom areas are considered, that the wider streams possess far greater amounts of food. In relation to planting of small trout these data show one very good reason why the smaller spring-fed tributaries make ideal planting places. In addition to an abundant food supply, an even flow of water is usually found with but very little variation in temperature from season to season. These conditions combine to offer an ideal environment for young fish. In the wider streams, on the other hand, flood and temperature conditions are usually extreme and the smaller trout are subject to far greater hazards with consequent greater losses.

In relation to the productivity of wide streams, the Klamath River in California should be mentioned. In this stream flood hazards have been reduced by the construction of power dams in its upper reaches near the Oregon line and its richness in aquatic fish foods is almost unbelieveable. One single sample taken in November, 1932, near Hornbrook, California, showed over 105 grams of food to be present. The stream at the point where this sample was taken was 210 ft. wide. Over 4,400 living organisms were counted from the one square foot. Of these 3,040 were the small operculate snails, *Fluminicola seminalis,* 1,517 were caddicefly larvae and pupae, mostly *Hydropsyche,* 300 were scuds, *Hyalella azteca,* 138 were mayfly nymphs, and a few other miscellaneous forms made up the remainder. This sample is the heaviest we have ever encountered in our bottom foods work, and the Klamath system as a unit is the richest drainage basin in production of aquatic foods that we have yet encountered. The water is exceedingly rich in organic matter picked up apparently as it flows first through Klamath Lake and later through the Copco Dam. In midsummer the water is usually green in color due to floating algae. Surprisingly enough, summer temperatures do not become too warm for salmonoid fishes and a rich population of both young steelhead

and salmon is supported. The Klamath is cited at this point merely to show that wide streams on occasion produce enormous amounts of food.

## Extreme Variability of Bottom Samples

It should be pointed out that in order to obtain fair averages of food conditions at any given point in a stream, it is necessary to secure a comparatively large number of samples, due to the great variability in the amounts of foods found from place to place in streams. For instance, the ten samples upon which the data for streams in the 1-6 ft. group in Table 1 are based, range from 0.65 gm. per sq. ft., the lightest sample in this series, to 4.19 gm. per sq. ft., the heaviest sample. Other samples in this series ran as follows: 2.5, 1.5, 3.97, 0.98, 0.99, 1.98, 1.01, and 2.85 grams respectively.

The weights in all of the other groups were equally variable, as for instance in the 7-12 ft. group they ran from 0.55 to 5.36 gm. Such extreme variation in the amounts of food is one of the salient points indicated in stream foods studies. It is practically impossible to predict with any great degree of accuracy the amount of food that will be found at any particular point where a sample is to be taken, though, with experience, it is possible to gauge roughly the relative richness.

## Seasonal Distribution of Foods

Reference to Table 2 shows the seasonal abundance of foods as found in Waddell Creek in California. This is a short coastal stream some 40 miles south of San Francisco. It averages about three feet in width at the end of the dry season in late October and early November, and in the rainy season is subject to severe floods when it will flow up to 500 cubic feet of water per second. Its average annual width is about twenty feet. Silver salmon and steelhead trout are abundant, adults of both species running in from the ocean during late fall, winter, and spring. The bottom is largely of gravel and small rubble with fine, deep pools at frequent intervals. The stream rises in the Santa Cruz Mountains and flows some 15 miles into the ocean. Before flowing into the ocean it flows through a lagoon for approximately one mile. Here brackish water conditions prevail, depending upon high tides, flood, or wave action. The foods samples were taken at a series of stations in the first three miles above the lagoon.

In an effort to determine the amounts of fish foods present at the various seasons, six series of from 11 to 14 samples each, were taken at varying periods. It is to be noted in Table 2, that there is considerable fluctuation in the amounts of foods present from season to season. The May series of samples were the richest of any obtained, giving an average of 18,254 organisms per square meter or

TABLE 2. SEASONAL ABUNDANCE OF BOTTOM FOODS IN WADDELL CREEK RIFFLES, 1932-1933

| Date | No. Samples | Ave. W. W. of Food per sq. ft. in grams | Ave. No. Organisms per sq. meter | W. W. Pounds of Food per acre. Riffle Area | Dominant Food Organisms |
|---|---|---|---|---|---|
| Aug. 23, 24, 25, 26, 1932 | 14 | 1.66 | 2,787 | 159 | Caddicefly larvae & pupae |
| Nov. 28, 29, 30, Dec. 1, 2, 1932 | 12 | 2.14 | 6,531 | 205 | Mayfly nymphs |
| Feb. 14, 15, 16, 1933 | 14 | 0.733 | 2,862 | 70 | Mayfly nymphs |
| March 30, 31, April 3, 4, 1933 | 12 | 0.907 | 2,324 | 87 | Mayfly nymphs |
| May 16, 17, 18, 19, 22, 23, 1933 | 13 | 4.92 | 18,254 | 472 | True-fly (Diptera) larvae & pupae |
| Aug. 29, 30, 31, Sept. 1, 2, 1933 | 11 | 1.94 | 6,262 | 186 | Caddicefly larvae & pupae |
| Totals and Averages | 76 | 2.05 | 6,503 | 196 | |

471 pounds of food per acre. This extreme richness was largely due to a superabundance of blackfly larvae (*Simulium*) which literally covered the stones in the shallow, swift riffles at this season of the year. The lowest amount obtained was in the February series where an average of only 2,862 organisms per square meter were found, giving the calculated amount of 70 pounds of food per acre.

It will be noted in several instances in Table 2 that high average number of organisms per square meter does not necessarily indicate high poundage of foods per acre. For instance, in the February series the number of organisms averaged 2,862 per square meter as noted above, and only 70 pounds per acre. The August series, on the other hand, showed 159 pounds of food per acre with but 2,787 organisms per square meter. Such apparent lack of correlation may be easily accounted for by differences in the body weights of the organisms taken in each series. In the February series many small sized forms were taken and their body weight was low, while in the August series fewer but heavier organisms were taken. Mayfly nymphs were dominant in the February samples while caddicefly larvae and pupae were dominant in August.

It is evident that there is a tremendous increase in stream bottom foods present in the spring season (May) in this stream. Miscellaneous collections in other California coastal streams likewise showed large increases at this time. It is fortunate that this seasonal increase in bottom foods takes place, for at this time the normal stream fish population is greatly augmented by steelhead and silver salmon hatching from naturally spawned eggs and the demand for food therefore is correspondingly increased.

The data in Table 2 indicate roughly two peaks of seasonal abundance of stream foods,—one in the spring and one in November-December. Whether similar seasonal variations would occur in

streams elsewhere under severe winter conditions remains to be seen. It is to be remembered that the dry season in California extends from late April to November when the streams become quite low and undoubtdly this factor is of prime importance ecologically. Winter conditions in Waddell Creek and other coastal streams are quite mild and are in no way comparable to winter conditions in streams in northeastern States.

Winter studies made in the High Sierra where conditions in winter are severe have shown about equal amounts of food to be present at this season of the year as compared with the warmer summer months. In the Merced River in the floor of the Yosemite Valley at an elevation of 4,200 feet, we found 103 pounds of food per acre, based upon four samples taken February 7 and 8, 1933. Four samples from this same riffle taken August 16, 1933, gave a production of 85 pounds per acre. Similar winter studies made under most difficult winter conditions in the Feather River near Lake Alamore in northern California indicate approximately similar amounts of food present at this season compared to summer. It is a rather common belief of many persons that fish should not be planted in the fall due to lack of foods in the streams during the winter. These findings are definitely contrary to this belief and it is evident from the little work done so far that there is at least as much food present, and perhaps more, in the winter than in the summer.

## Variable Amounts of Food Found From Season to Season in the Same Riffle

In Table 3 are shown the seasonal amounts of food found in the same riffle (Sta. 2) in Waddell Creek. The figures for February, April and May are the average of three samples taken in each of these months at Station 2, but all the other figures are the weights obtained from single samples only.

TABLE 3. AMOUNT OF FOOD FOUND IN THE SAME RIFFLE* AT VARYING SEASONS OF THE YEAR

| Date | No. Samples | Width | Depth | Wt. of Food in grams per sq. ft. |
|---|---|---|---|---|
| August 25, 1932 | 1 | 8 ft. | 6 in. | 3.63 |
| November 28, 1932 | 1 | 8 ft. | 5 in. | 5.23 |
| February 15, 1933 | 3 | 20 ft. | 6 in. | 0.648 |
| April 4, 1933 | 3 | 21 ft. | 7 in. | 1.14 |
| May 17, 1933 | 3 | 21 ft. | 4 in. | 5.00 |
| August 30, 1933 | 1 | 12 ft. | 3 in. | 1.67 |

*This riffle was located about one mile from the ocean in the lower part of Waddell Creek. Its length was approximately 100 ft. and the water was swift in it at all times. The bottom at all times consisted of coarse gravel mixed with fine gravel and sand. Seasonal variations in volume of flow account for varying widths and depths listed.

Here the same seasonal trends are evident as were shown in Table 2 for the whole stream. Though the fluctuation in weight of nutritive elements found from time to time is greater here, this

would naturally be expected when production from individual samples is recorded rather than averages from a series of samples. These figures are given here merely to show that the results from a single riffle did follow the seasonal trend though with considerable variation both above and below the monthly average for the stream as a whole.

## Relation of Types of Bottom to Amounts of Food

By averaging weights of food obtained in the different types of bottom in Waddell riffles, all rubble (large and small) was found to shelter the most, averaging 3.38 gm. per sq. ft. Large rubble alone produced 2.16 gm., coarse gravel, 1.31 gm., and fine gravel, 0.92 gm. respectively. These figures, with the exception of that given for rubble, represent about the same amounts of food as the writer found in similar types of bottom in streams of central New York and agree closely with those of Pate (1932).

While the Waddell Creek samples were taken at varying seasons of the year and those in New York only in the summer months, it is interesting to compare the gross results in pounds of food per acre found in each. In the former the annual average was 196 pounds per acre and in the latter only 97 pounds per acre, or less than half as much.

Pools in Waddell Creek showed an average of only 54 pounds of food per acre to be present, while as noted above, riffles gave approximately four times this amount. This figure can be applied only to bare pool bottoms. Many pools that have "side-eddy" settling basins have been found to produce tremendous amounts of foods in certain instances. In one such sample in Waddell Creek we obtained over 10 grams of food from one sq. ft. Other samples taken from the same pool ranged from .46 gm. to 5.63 gm., showing the same extreme variability as the riffle samples.

## Contribution by Weight as Compared to Numbers of the Major Groups of Aquatic Insects

In the spring of 1934, instead of weighing total organisms taken in each sample, as had been done previously, it was thought desirable to determine the contribution by weight as well as numbers for the four major groups of aquatic insects: caddiceflies, mayflies, true-flies (Diptera), and stoneflies. This was done in 13 samples and the data are submitted in Table 4. Here it is at once evident that larger numbers do not by any means indicate greater weight of food. Caddicefly larvae and pupae which formed only 22.2 per cent of the total number of organisms taken in the 13 samples formed 43.9 per cent of the total wet weight of all organisms, thus offering the most food in actual bulk of the four groups. Mayfly nymphs, on the other hand, were most abundant forming over 55 per cent by

number but only 28 per cent by weight. Stonefly nymphs were third in weight at 12.2 per cent and fourth in numbers at 7.8 per cent. Thus, as has been shown previously in trout stomach examinations by many workers and by the data submitted here, the caddiceflies are the most important single group of trout food organisms.

TABLE 4. MAJOR GROUPS OF AQUATIC INSECTS AND THEIR CONTRIBUTION BY WEIGHT AND NUMBERS TO AVAILABLE FOOD SUPPLY OF WADDELL CREEK RIFFLES*

| | Total No. | Per cent | Total Wet Weight in Grams | Per cent |
|---|---|---|---|---|
| Caddicefly larvae and pupae | 891 | 22.2 | 6.79 | 43.9 |
| Mayfly nymphs | 2,224 | 55.5 | 4.33 | 28.0 |
| Diptera larvae and pupae | 412 | 10.3 | 1.22 | 7.9 |
| Stonefly nymphs | 312 | 7.8 | 1.89 | 12.2 |
| Miscellaneous | 164 | 4.1 | 1.22 | 7.9 |
| Totals | 4,003 | — | 15.45 | — |

*Based on 13 samples taken Feb. 14, 15, 28, Mar. 1, 2, 20, 22, 1934.

## Factors Governing Distribution of Bottom Foods

As pointed out by Needham and Pate, the major factors involved in the distribution of bottom foods are type of bottom, speed of current, and depth. Temperature likewise is important and, as a general rule, warm streams are richer in foods than cold ones. Oxygen content of the water likewise may be important, as pointed out by Pate (1932). However, in no case has it been possible to correlate abundance of foods with amounts of this gas in water. It seems evident to the writer at least, that of all complex, closely-interrelated factors of depth, type of bottom, current, light, gases in solution, plant life, presence or absence of predators, etc., that depth, bottom and current are the really limiting conditions which, acting together, make for either richness or scarcity of stream foods. Light is dependent upon depth. Deep swift riffles produce less food than shallow swift riffles. Light is required for photosynthesis by the microscopic phyto-plankton that forms the slimy ooze on stones and the shallow areas offer good light conditions. These aquatic plants are to the streams what the grass is to the land; the primary source of food of the larger herbivorous forms. Hence it would seem only natural that aquatic insects would be found where their food is most abundant.

No effort has been made to give the individual data for each sample here, due to lack of space, and merely gross results are submitted. These should be considered tentative pending further investigations. We have been measuring only standing crops. But there is far more that remains to be learned and more that is directly applicable to stocking problems than this. We do not know what percentage of the total potential stream foods can actually be secured as food by trout, nor what the rate of replacement of foods is from season to season. Also, we do not know the very impor-

tant matter of how many pounds of natural foods it takes to produce a pound of trout.

In order to develop well planned stocking policies, the old fact-finding agricultural methods must be applied. Yield of pounds of fish per acre of water is just as important for aquiculturists to know as it is for farmers to know yield per acre in potatoes, corn, or any other product, if maximum production is to be attained.

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# CALIFORNIA STEELHEAD EXPERIMENTS

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Those who do not live in regions where steelhead trout are native have undoubtedly become familiar with them as rainbow trout for they have been very widely spread by introduction. Of course, one of the characteristics of the steelhead is their migratory habit that takes them from their nursery streams to larger bodies of water to mature. This accounts for their large size at maturity and also for most of the problems that arise in the management of steelhead streams.

The old question as to differences between the rainbow and steelhead, particularly as to their migratory habit, is still a very live one in California and it is receiving considerable attention in other parts of the country. At present it is our opinion in California that trout of the rainbow series are all definitely migratory and that no sharply dividing line separating steelhead from rainbow will be found. In all waters harboring fish of the rainbow type there appears to be a gradation in the migratory habit that is limited largely by the physical characteristics of the stream or lake. Typical steelhead streams such as the Klamath also have fish which have reached maturity without ever having migrated to the ocean. These fish are most common at the headwaters of the tributary streams but an occasional fish of this type is taken in the main river. On the other hand, we have in the Pit River fish of rainbow type which mature in the main river and migrate into the smaller tributaries to spawn and at the same time in the lower portion of the watershed there is a considerable run of ocean fish. Even among fish that are definitely of the steelhead type which migrate to the ocean to attain maturity, various degrees of this habit are found. It is a well known fact that some of the young steelhead go to the ocean in their first year, some in their second, and a smaller number in their third year. Quite a few of these fish, especially the males, reach maturity in their second year and some of the males and females reach maturity in their third year. Thus even within the group of fish that we definitely consider as steelhead may be found such gradations in the time of maturity and migration as would make them overlap in these characteristics with fish that are commonly considered as rainbow.

The purely practical importance of this subject lies in the fact that, at a certain time of the year the trout found in California coastal streams are for the most part very small, being steelhead

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**NOTE:—The writer wishes to thank Mr. Leo Shapovalov for his assistance in this work.**

belonging to the first and second year groups. These small fish are present in considerable numbers, but even with a limit of twenty-five they do not furnish very satisfactory fishing because of their small size. It should be explained here that the trout fishing is open in these steelhead streams for from nine to ten months of the year. In the Klamath for instance, the fishing in the main river during the months of May, June, and July is almost entirely for these small steelhead and such young salmon as may be taken incidentally. The mature salmon and steelhead start to come into the river in considerable numbers during the latter part of July and the season on these larger fish is open from then until February 28.

In some parts this might be considered as satisfactory trout fishing but there has recently been some demand to supply large fish in the early part of the season as well as during the fall and winter months. It is doubtful if it would be desirable to try to maintain large trout in the same streams with the young steelhead. Nevertheless, it is an example of the type of problem that is being put up to the California Trout Investigation for solution. To meet such problems as this and in addition a number of others that are fundamental to the proper management of the steelhead streams, an experimental project has been developed to be carried forward over a number of years.

Scott and Waddell Creeks have been selected for experimental work. They are both small streams flowing into the ocean about forty miles south of San Francisco, their watersheds adjoin and the mouths are separated by only five miles of coast line. The creeks are very similar in size, being about fifteen miles in length. Small streams have been selected because of the obvious advantages they offer in permitting examination of the entire run of salmon and steelhead entering such streams and of most of the migrants leaving them.

Scott Creek has been used by the California Division of Fish and Game as the site for a steelhead egg-taking station for over twenty years and is unique in that some years ago the lower two miles of the stream were set aside by the legislature as a fish refuge. Game refuges are common enough but a fish refuge is quite unusual, at least in California. The egg-taking station is situated about two miles from the mouth of the stream and consists of a concrete dam four feet high with an apron sixteen feet wide and a fish ladder at one side. The fish are unable to jump the dam by reason of the wide apron and the shallow, swiftly flowing water that covers it. From the ladder the fish pass into a side channel that carries them back into the holding tanks of the station. This type of automatic trap is a very practical one in such situations for it allows the flood waters and debris to pass freely downstream and, at the same time, intercepts all of the fish moving upstream. The fish move in these streams shortly after the peak of high water, and it is practically impossible to maintain the ordinary type of picket weir.

A similar dam was constructed in Waddell Creek during the summer of 1933. It differs chiefly in the fact that it was so built that it would take not only all of the adult fish moving upstream to spawn but also the greater part of the small fish migrating to the ocean. The adult fish moving upstream are taken with a fish ladder combined with a trap as at Scott Creek. The water supplying the ladder is first taken through two screened tanks in order to catch fish moving downstream. This water is taken from one side of the dam and just below the crest. During high water most of the flow goes over the crest as the screens in the trap can not handle more than six or seven cubic feet of water per second. We have found that very few of the small fish migrate during high water. Those migrating while a moderate amount of water is going over the dam avoid the crest and tend to follow the subsurface flow of water into the traps. It is not essential to the success of our experiments that all of the downstream migrants be taken in the trap as we planned to arrive at their number through a calculation based on the proportion of marked to unmarked fish among those returning from the ocean at maturity. All the small fish taken in the traps are marked by the clipping of fins.

Our experimental set-up thus consists of two adjacent streams in which we can take a complete annual census of the fish returning from the ocean and in one of them we will also be able to determine the number of naturally spawned fish migrating to the ocean each year. In Scott Creek there is little natural spawning as practically all of the eggs are taken for hatchery use. In that stream we will be able to determine the number of fish returning from plants of different kinds, such as size of fish and season of year.

It is obvious that in the above determinations it is assumed that the fish return to their parent stream. Considerable information is available as to the homing instinct of certain of the salmon but little or no work of this sort has been done on the steelhead although there is considerable indirect evidence that they do so return. It is essential to our experiments, however, to know to what extent straying occurs and this should certainly be at a maximum in these two streams the mouths of which are separated by only five miles of coast and that are so similar in physical characteristics. Any interchange that occurs will be known through the returns of marked fish.

We will also be able to determine many other facts relating to life history, such as age, growth rate, and the migratory habits of the young fish. The latter knowledge is particularly desired in order to give the maximum protection through properly framed regulations.

Another problem that is of immediate practical concern is the production of a supply of steelhead eggs for the use of the hatcheries. It is becoming increasingly difficult to maintain a sufficient supply of these eggs as most of them are now taken in heavily fished

streams, such as the Klamath. It is of the utmost importance that dependable sources for these eggs be developed, sources that will be free from the effects of angling and that can be developed to maximum productivity. At Scott Creek we are making heavy plants in order to determine the maximum productivity of this small stream.

At present our experimental work is well under way but our results are just beginning to accumulate. At Scott Creek two plantings of marked fish have been made and data have been obtained on the egg production of fish of various sizes and ages. We have also done considerable tagging of the adult fish but we have found no really satisfactory method of tagging.

The trap on Waddell Creek was put in operation in September of 1933. To date about seven thousand fish have been handled. This has included 463 adult silver salmon, 418 adult steelhead, 3,277 silver salmon migrants, and 2,450 migrating steelhead. All of the adults were measured and sexed. Scale samples were taken from large numbers of migrants.

The movement of steelhead in and out of most of the coastal streams is limited by the closure of the mouths of the lagoons by sand bars. These sand bars are taken out by the first heavy rains of November or December. The silver salmon start to run almost immediately and the steelhead follow shortly afterward. In 1933 the silver salmon run started about December 1 and extended until February 15 with a peak on January 1. The steelhead run started about December 15 and continued for a somewhat longer period, or until about April 15. The period of the run is known to vary somewhat from stream to stream, and, as was said before, in the smaller streams it is limited by the opening of the bar. Even the mouth of the Klamath is occasionally closed for short periods but in it and some of the larger streams the run starts earlier and extends over a longer period. This year steelhead started to come into the Klamath in July and the run usually continues until December.

We were particularly interested in determining the time and extent of the seaward migration of both the steelhead and silver salmon. The former started a definite migration during the week ending February 24 and the movement reached a high point during April as three to four hundred fish moved during each week of that month. By June 1 the migration was practically completed.

The movement of silver salmon extended through nearly the same period, but the bulk of the migration was concentrated within the period from April 15 to May 15. We were also very much interested to find that the two species of Cottidae inhabiting the stream, *Cottus asper* and *Cottus gulosus* migrate downstream to spawn—3,900 of these fish were taken from the traps during the months of January, February, and March and passed on downstream. The high development of the ovaries indicated that they were on a spawning migration.

# ULCER DISEASE OF TROUT

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During the summer of 1933, lesions of a disease were noted among some fingerling brook, rainbow, blackspotted, and lake trout at the Cortland (New York) trout hatchery. Although these lesions bore a marked superficial resemblance to those of furunculosis, they were sufficiently atypical to warrant further investigation. A more detailed examination of the lesions proved them to be of a distinct disease, which for lack of a better name is herein called "ulcer disease," for the lesions closely resemble those previously described by Calkins (1899) under this name. Because of the marked resemblance to furunculosis, ulcer disease has not been generally recognized by trout culturists, and any ulcer appearing on fish has been ascribed by them to furunculosis without further question.

Because of this confusion, it is impossible to determine, with any great degree of accuracy, the geographical distribution of ulcer disease. Calkins found a similar disease in a commercial trout hatchery at Northport, Long Island, in 1899 and reported the same disease as having appeared among the trout at a neighboring hatchery ten years previously. Marsh reported a disease of similar appearance at the State Trout Hatchery at Cold Spring Harbor, Long Island, in 1904. This author found the same disease among wild fish at Alder Lake, (Ulster County) New York, fourteen years later. Fingerling brook trout exhibiting definite lesions of ulcer disease have been sent to the Pathology Laboratory of the U. S. Bureau of Fisheries from a trout hatchery in northern Pennsylvania. Mention of ulcer disease as distinct from furunculosis was made in a personal communication to the bureau by an investigator in Michigan. During this investigation, ulcer disease was found at two hatcheries in upstate New York, and it probably exists, unrecognized, throughout the greater part of northeastern United States.

This report, admittedly incomplete, is published for three reasons: (1) to revive the interest of fish culturists in this disease; (2) to place on record the results of this investigation as an aid to other investigators who may, in the future, find interest in this disease; and (3) to inform investigators of furunculosis that trout are subject to a disease closely resembling furunculosis, yet progressing in an entirely different manner. Thus it is hoped that the inevitable confusion arising from conclusions attributed to furunculosis but actually due to ulcer disease may be avoided.

## Causative Agent

Inasmuch as the disease appeared to be of bacterial etiology, an effort was made during this investigation to isolate the causative organism. The body surfaces of infected fish were sterilized with tincture of iodine following which, the lesion was swabbed with a sterile bit of cotton affixed to an applicator. The material on the cotton swab was then transferred to a tube of sterile Difco nutrient broth and incubated at room temperature. As might be expected, some 23 different organisms were recovered from the open lesions and isolated in pure culture. With one exception, all of the organisms so recovered and isolated proved non-pathogenic when inoculated either subcutaneously or intradermally into fresh rainbow and brook trout fingerlings. Inasmuch as the one exception noted resembled in size and shape an organism observed in both smears and sections of all types of lesions, further effort was made to determine the morphological and cultural characteristics of the pathogenic organism with the following results.*

Morphology—small rod—1.5 m. x .6 m.
Actively motile
Gram negative
Spores absent
Agar plates—translucent, whitish, somewhat spreading, colonies
Carbohydrate reactions:

Lactose—no acid, no gas

$$\left.\begin{array}{l}\text{Dextrose}\\ \text{Saccharose}\\ \text{Salicin}\\ \text{Maltose}\\ \text{Mannite}\end{array}\right\}\text{ acid and gas}$$

Litmus milk—decolorized, peptonized
Gelatin stab—rapid, infundibuliform liquefaction
Loeffler's serum slants—digested (liquefied)
Nitrates reduced
Indol positive
Potato—heavy, pinkish brown growth

Diagnosis—Genus *Proteus*, probably *hydrophilus*

Inasmuch as *Proteus hydrophilus* is a well known natural pathogen of frogs, and an experimental pathogen of fish, and therefore might presumably be relatively common in certain water supplies, the possibility remains that *Proteus hydrophilus* was merely playing the role of a secondary invader in the lesions of ulcer disease and the fact that it happens to be of the same size and shape as the organism in the sectioned tissues, merely a coincidence. Further experimental work is planned to clarify this point.

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*I am indebted to Dr. Marvin M. Harris of the Johns Hopkins University for assistance in the identification of this organism.

## Pathology—Gross

Apparently the earliest lesion of ulcer disease appearing on the body surface of an infected host is a definite thickening of the epithelium over a small area producing an inconspicuous white patch. This patch, which may measure 0.5 to 5.0 millimeters, rapidly loosens from the body surface and produces a picture not unlike a very small growth of the fungus *Saprolegnia.* Such a condition is best described as an "epithelial tuft." This tuft of epithelium is most obvious when one looks directly down upon the fish swimming about in a trough.

The appearance of this epithelial tuft is soon followed by a fading of the pigments of the skin underlying the area and is eventually followed by a definite perforation of the skin and the formation of a small ulcer. In some instances, previous to the perforation of the skin, the tissue underlying the epithelial tuft shows a marked reddening due to a localized congestion of the blood vessels.

When the lesion of ulcer disease appears on the fin of a fish, it destroys the soft tissue between the fin rays, leaving the more durable rays projecting beyond the necrotic tissue. The area of necrosis advances more or less in a horizontal line towards the base of the fin. A thickening of the epithelium in response to the irritation appears as a definite white line bounding the proximal margin of the necrotic area. In advanced fin lesions, the entire fin may be destroyed and the infection progresses deep into the muscular tissue about the base of the destroyed fin. The dorsal fin appears to be the only part of the body surface particularly susceptible to attack for it is usually, but not always, involved.

A typical ulcer so formed on the body surface of a trout appears well defined, usually circular in outline, and gives very little evidence of undermining. The crater of the ulcer varies in depth, not always in direct porportion to the area of body surface involved. The color of the concave surface of the ulcer varies from a tissue grey to a dark red, the color apparently depending upon the amount of blood exuding into the lesion from the surrounding blood vessels. The red coloration of the concave surface of the ulcer, when present, is very superficial and may easily be wiped away, leaving the greyish white muscular tissue exhibiting little, if any, evidence of hemorrhage. The ulcers on fingerling fish may attain a diameter of one centimeter and on bigger fish, ulcers of considerably larger size have been observed. (See plates 1 and 2.)

Apparently the dead tissue of the lesion is sloughed away soon after it forms, thus accounting for the rapid growth in the size of an ulcer. This sloughing of necrotic tissue likewise may explain the lack of fungus growth, which never accompanies this disease until after the death of the host. In one instance, a luxurious growth of *Saprolegnia* appeared on the ulcers of an infected fish within 24 hours after death, although live fish in the same trough having ulcers equally as large as

those on the dead fish so fungussed, exhibited no trace of fungus growth.

There is no evidence that ulcer disease even invades the internal organs. One may find a general inflammatory reaction throughout the viscera of heavily infected hosts, but no visible areas of necrosis have been observed.

Macroscopically, ulcer disease may easily be confused with furunculosis or with fin rot, two common diseases of hatchery trout. Between the lesions of ulcer disease and those of furunculosis there are several points of difference, although border line cases may be found, particularly on fingerling fish, which are exceedingly hard to diagnose accurately without resorting to microscopy. In the first place, the lesions of ulcer disease do not support fungus during the life of the host. The lesions of furunculosis, however, usually support a luxuriant growth of *Saprolegnia* which at times becomes sufficiently abundant to completely mask the lesion. Secondly, in ulcer disease, the lesions are clear cut, the visible necrosis not extending much deeper than the surface of the ulcer, and the whole picture is typical of a sloughing necrosis progressing from the external surfaces inward. Furunculosis, being an internal infection working towards the surface, produces subcutaneous boils, or blisters, full of necrotic debris and red blood cells. These blisters eventually perforate the epithelium. An ulcer, so formed in furunculosis, usually appears heavily undermined, irregular in margin, and to reach the solid musculature, one must excavate large quantities of necrotic debris from the cavity of the lesion.

Although the lesions of ulcer disease are characteristically different from those of furunculosis, no such definite difference may be found between this disease and fin rot. Davis (1927) in his original work on fin rot, describes body lesions comparable to those of ulcer disease. At present, fin rot presents no small enigma and needs further investigation. A necrotic area on the fin of a trout commonly signifies one of several conditions. In the first place, it may result from "nibbling" by another fish. The lesions produced by nibbling, unless secondarily infected, usually heal quickly with a definite thick white line of epithelium completely and smoothly capping the wounded area. Fin rot, the second condition, is produced by a definite, although possibly not a specific, bacterial invasion. The lesions are indistinguishable from the fin lesions of ulcer disease except for the unsatisfactory difference that fin rot infections often may be checked by dipping the fish in a disinfecting solution, whereas this method is not very effective in checking advanced cases of ulcer disease. It seems quite probable that the organism responsible for ulcer disease is merely one of many fresh water organisms capable of growing in injured fish tissue. Ulcer disease, therefore, when confined to the fins may well be regarded as a virulent form of fin rot.

## Pathology—Microscopic

The microscopic pathology of ulcer disease is that typical of an external bacterial invasion. Histological studies of the blood, liver, spleen, and kidneys of infected hosts confirmed the general lack of macroscopic lesions in the viscera and it is concluded, in the light of evidence now available, that ulcer disease does not involve, directly, any tissue other than the skin and underlying musculature. It is possible that the etiological agent is capable of toxin production which may be absorbed from the lesions and so may in part account for the heavy mortality accompanying this disease. This tentative conclusion is based upon the large amount of microscopical necrosis surrounding a relatively small accumulation of bacteria. Microscopic areas of necrosis have likewise been found in the liver and some tubular necrosis in the kidneys of heavily infected hosts sacrificed at the point of death. These areas show no evidence of bacterial invasion and the lack of cellular infiltration about these areas may, but may not necessarily, indicate the action of a cytolytic toxin.

It seems quite probable that the primary site of the infection is at a point of injury to the normal epithelium. Whether the causative agent is capable of independent penetration of the epithelium is not known. The first protective response to the infection is a marked thickening of the epithelium, which is responsible for the appearance of the epithelial tufts and the white line of the fin lesions. At this time, the bacteria may be found in a localized area between the base of the epithelium and the subepithelial connective tissue. (See plates 3 and 4). A slight infiltration of polymorphonuclear leucocytes is noticeable. A progressive necrosis extends in all directions from this picture as the disease progresses which results in a complete disintegration and sloughing of the epithelium, scales, and subepithelial connective tissue. Eventually a clean ulcer extending to the subcutaneous connective tissue is formed. A marked infiltration of polymorphonuclear leucocytes and red blood cells is then noticeable in the tissues surrounding the lesion. This leucocytic response to ulcer disease definitely differentiates this disease from furunculosis in which no such infiltration has been observed. It is doubtful, however, if this polynuclear response is specific to ulcer disease, although such a response has not been reported from any other disease of fish.

The heavy subcutaneous connective tissue band forming the corium of the skin apparently offers very little resistance to the bacteria and sooner or later is penetrated exposing the skeletal musculature. The result of this perforation of the skin is a marked hyalinization of the underlying muscle bundles. The bacteria grow in the accumulation of necrotic debris resulting from the death and subsequent disintegration of the muscle bundles and the whole picture is one of a progressing ulcer of the skin, stubbornly resisted by the polymorphs of the host. The leucocytic counter attack appears to be successful at times, although

the circumstances attending such success are unknown. During this investigation, ulcers which had apparently healed over were observed on some of the older fish. Subsequent histological examination of these ulcers showed the surface of the former lesion to be covered by a thin layer of epithelium and the area of destroyed musculature more or less completely repaired by scar tissue. The region was abundantly supplied with blood vessels and gave every indication of being a complete and successful repair of the damage done by the infection. The infiltration of leucocytes was still present in these healing ulcers, although the majority of the wandering cells were of the mononuclear type. Marsh (1904, 1918) reports apparent healing of lesions found on both hatchery and wild fish.

## Control

At present, there are no effective control measures available after the disease once gains a foothold. The only hope of checking the disease is in its earliest stages when a quick recognition of the symptoms and the prompt administration of a bactericidal dipping, such as copper sulphate may result in an effective control of the disease. After the bacteria have initiated the proliferation of the epithelium and they have worked down into the tissues, there is little chance of reaching them with any of the known disinfectants.

An epidemic may be avoided at any hatchery where the disease is known to occur by employing rigid sanitary precautions. The distribution of fish from the relatively few hatcheries now troubled with ulcer disease to hatcheries where it does not occur should be stopped.

## Discussion

While the lesions of ulcer disease and those of furunculosis may be strikingly similar in gross appearance, nevertheless, it is of extreme importance that the fish culturist and the scientific investigator be able to differentiate between the two diseases.

Furunculosis, being an internal infection, cannot be controlled by any method which we know. Ulcer disease, on the contrary, being an external infection, can be controlled at least in its earlier stages by the application of a bactericidal dipping. Hence, the fish culturist when confronted by an epidemic of ulcer disease in his hatchery may be able to save many of his fish by prompt activity when the epidemic first appears.

The scientific investigators, particularly those working on furunculosis, must differentiate between the two diseases to avoid erroneous conclusions and the inevitable confusion arising from such conclusions. It is believed that the few "cures" already reported for furunculosis based entirely upon the disappearance of clinical manifestations, actually may have been unrecognized infections of ulcer disease in which spontaneous recovery has been found, and that furunculosis was in no

way involved. Certainly, no scientific conclusions concerning furunculosis or ulcer disease can be accepted in the future without confirming bacteriological and histological evidence.

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## ULCER DISEASE LESIONS

Plate 1

Ulcer on five-inch blackspotted trout. None of the fins are affected. Note the "clean" appearance on the concave surface of the lesion.

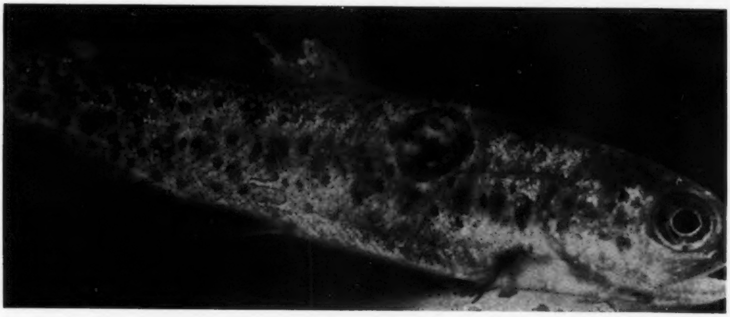

Plate 2

Ulcer on four-inch blackspotted trout. The dorsal fin is likewise infected. Note the small hemorrhagic spots in the cavity of the ulcer.

# PHOTOMICROGRAPHS OF EARLY LESIONS OF ULCER DISEASE

**Symbols Used in Plates 3 and 4.** B, bacteria; B.M., body muscles; C, heavy connective tissue band forming the corium of the skin; Ct, subepithelial connective tissue band forming the scale pockets; E, epithelium of skin; L.L., lateral line complex; S, scale.

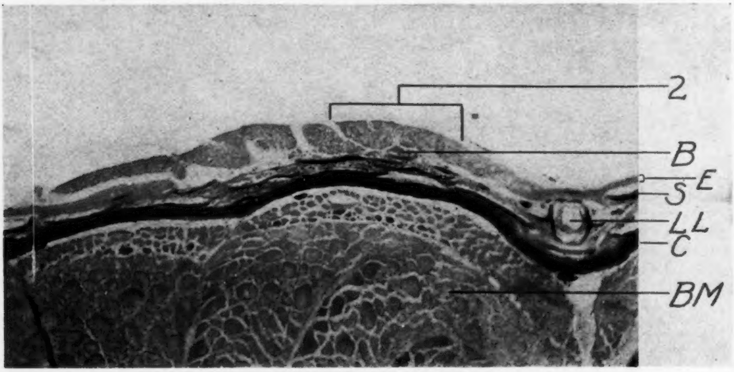


Plate 3

**Low power view of brook trout skin section through an epithelial tuft E indicates the normal thickness of epithelium as a comparison with the thickness of the epithelium in the invaded area partially inclosed in bracket 2. Enlarged approximately 100 diameters.**

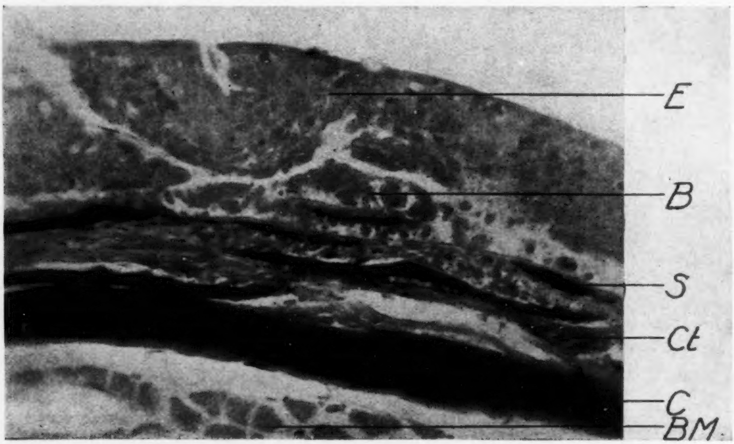


Plate 4

**High power view of area enclosed in bracket 2 of Plate 3. Note the location of the bacteria *under* the epithelium—which explains the difficulty of reaching them with external disinfectants. Enlarged approximately 400 diameters.**

# THE GOLDEN TROUT OF COTTONWOOD LAKES
## (*Salmo agua-bonita* Jordan)*

BRIAN CURTIS

In 1904 Dr. Barton Warren Evermann made an exploratory investigation of the golden trout of the Southern High Sierras of California. He listed three species:

*Salmo whitei* Evermann from Soda Creek,

*Salmo roosevelti* Evermann from what was then called Volcano Creek but is now mapped as Golden Trout Creek, and

*Salmo agua-bonita* Jordan from the South Fork of the Kern River. Soda Creek is a tributary of the Kern River from the west, but the two last-named are small streams which flow into it from the east, not far from Mount Whitney.

He also established the fact that it was from Mulkey Creek, a tributary of the South Fork of Kern, that in 1876 thirteen fish were carried by ranchers in a tea-pot across the divide into Cottonwood Creek, about six miles away, and that therefore it was *Salmo agua-bonita* which was to be found in Cottonwood Creek, which he did not visit. He noted that the fish in "Volcano" Creek and the South Fork of Kern were very numerous, but were also very easy to catch and very restricted in distribution, and for that reason he feared that, in spite of their accessibility only by pack-trail, they were in danger of extinction. His program, which was necessarily limited, included no attempt to study the life-history of the fish, and until the present work was undertaken no such study had been made.

The principal change which has taken place since Dr. Evermann's exploration has to do with the fish which were transplanted to Cottonwood Creek. Here they grew and flourished, and in 1891 a further transplant was made, again by ranchers, to the lakes above the impassable falls on the main branch of this creek. These in turn grew and flourished, and eventually were utilized by the California Division of Fish and Game as a source of eggs for artificial propagation at the Mt. Whitney Hatchery, from which the fry were and still are planted in suitable waters throughout that section of the Sierras. The result is that *Salmo agua-bonita* is no longer a species vulnerably isolated in a small stream, but is distributed throughout the high waters of the southern mountains, and the extinction of the species is practically impossible, especially since the closing of one of the Cottonwood Lakes to all fishing in 1930.

*This paper is based on material prepared for a thesis submitted to the Department of Zoology and the Committee on Graduate Study of the Leland Stanford Junior University in partial fulfillment of the requirements for the degree of Master of Arts. The work was carried out with the co-opeation of the California Trout Investigation, a joint enterprise of the U. S. Bureau of Fisheries and the California Division of Fish and Game, and acknowledgement is hereby made of the valuable assistance furnished by both of these agencies, and especially by Dr. J. O. Snyder, Dr. Paul R. Needham, and Mr. Alan C. Taft.

The fish of Cottonwood Lakes were chosen for this study partly because of their strategic importance in the artificial distribution of the golden trout, partly because of their accessibility, but above all because of the fact that the egg-taking operations there made it possible to obtain, with the co-operation of the hatcherymen, material which could only with great difficulty have been obtained in any other way.

The Cottonwood Lakes are situated in Inyo County, less than ten miles in a straight line southeast of Mt. Whitney, but cut off from it by intervening ranges. Their elevation is approximately 11,000 feet. They are reached by trail from Lone Pine, in the Owens River Valley, the fifteen mile climb from the pack station outside the town taking about six hours. They are six in number, with the uppermost not used for egg-taking. They range in surface area from the five acres of Lake 2 to the thirty acres of Lake 4. They range in depth from the four-foot maximum of Lake 1 to the seventy-seven feet measured in Lake 5. They are ice-covered from October to June. In the summer of 1933 the maximum recorded water temperature in Lake 3 was 64° F. They lie in a glaciated valley at tree-line, surrounded by treeless granite cliffs. The five lower lakes form two separate systems of fish population, lakes 1, 2 and 3 being cut off from the creek below by impassable falls, and from lakes 4 and 5 above by impassable falls, while other impassable falls isolate Lake 6. The total difference in elevation between lakes 1 and 5 is about 180 feet. The golden trout is the only fish inhabiting the Cottonwood Lakes and Cottonwood Creek. Its characteristics show great variability in the different waters, as will be brought out later, and it must therefore be stressed that statements made in this paper apply only to the fish in the particular waters specified.

The work of egg-taking is arduous. It begins when the ice starts to go out in June and lasts about a month. Traps or screens are placed at the inlets of the lakes, and also, because the golden trout will run downstream as well as upstream to spawn, at the outlets. The traps must be cleared daily, and every third or fourth day the ripe females must be stripped. The workers stand in water up to the tops of their boots, exposed to wind, rain, hail and snow. The eggs are more delicate than those of any other of the trouts, and must be handled with great care to avoid injury. They are kept overnight in special cans in the stream, and at daybreak are loaded on mule-back, taken down the mountain to the pack-station, and transported from there by motor to the Mt. Whitney Hatchery, twenty miles away, with the air temperature, by the time they arrive, anywhere from twice to three times what it was when they started their journey in the morning.

During the egg-taking operations in 1933, data were obtained from over 450 female fish. Scales were taken, over-all lengths were measured, and the quantity of eggs produced by each female was cal-

culated by a method devised by Mr. Alan C. Taft of the U. S. Bureau of Fisheries which involved the gross volume of the eggs as read in a graduate, the size per egg, and a reduction factor. The methods used permitted the securing of these data without destroying either the fish or the eggs.

From these data, and from observations, measurements, experiments, samples, and dredge and plankton-hauls made during the rest of the summer, was synthesized the life-history which follows:

The golden trout of Cottonwood Lakes begin to spawn in June, as the water temperature approaches 50° F. They spawn with equal facility in the inlet or the outlet of a lake. The egg production of the female increases on the average in direct proportion to the increase in over-all length. The relationship is expressed by the equation $y = 41.1\ x - 508$, in which y is the number of eggs, x the length of the fish in centimeters. This means that the average number of eggs is about 305 for a 20 cm. fish, about 715 for a 30 cm. fish, and about 1,030 for a 37.5 cm. fish. These figures refer to the number of eggs stripped from the fish. As the operator left on the average 7% in the fish, the actual total number of eggs in the fish averages 107% of the number shown.

The hatching period of the eggs corresponds very closely to that of the rainbow. This was determined by running two lots of golden trout eggs in trays in the outlet to Lake 3 and comparing the results with figures very kindly furnished by Dr. G. C. Embody. The two lots of golden trout eggs behaved in almost identical fashion, requiring 520 and 528 temperature units for hatching. The two lots averaged 20 days to hatch at an average temperature of 58.2°, while Dr. Embody's figures show 20-21 days required for the rainbow at average temperature of 57.2°. These golden trout eggs were "eyed out" at the end of 12 days. The experimental fry were about 1.5 cm. long when hatched, and it took 18 days for them to absorb the yolk-sac, at the end of which time they were nearly 2.5 cm. long. Native fry, spawned by fish which had escaped the traps, gave evidence of very rapid growth the first summer, doubling their weight every ten or twelve days in Lake 3 outlet and far outstripping the hatchery-reared fry, as may be seen from the following figures:

| | Average Length August 1 1st appearance | Average Length August 12 | Average Length September 2 |
|---|---|---|---|
| Native fry, Lake 3 | 2.3 cm. | 3.0 cm. | 4.3 cm. |
| Native fry, Lake 4 | | 2.6 cm. | 3.3 cm. |
| Hatchery fry, measured at first planting August 29 | | | 2.3 cm. |

The difference between the Lake 4 and the Lake 3 native fry can be accounted for by later spawning in Lake 4, and possibly also by a smaller food supply in the stream there.

The fry begin to form scales at a length of about 4.5 centimeters,

and at about the same time begin to migrate into the lakes. The first native fry were seen in Lake 3 in 1933 toward the end of August, and averaged just under 5 cm. in length.

The growth-rate was calculated from the actual measured lengths of spawning fish, and from scale measurements. The scales of this fish are small, but are easily read, showing in most cases distinct annual checks, and easily distinguishable spawning checks. Statistical analysis having proved that the increase in length of scale is proportional to increase in length of fish in this species, Dr. C. McLean Fraser's formula was used, which postulates that the length of the fish at the time of any previous annual check minus the unscaled length (here 4.5 cm.) is to the present length of the fish minus the unscaled length, as the distance from the first ring of the scale to the annual check in question is to the distance from the first ring to the margin.

An unforeseen difficulty was the fact that some fish, among which are probably to be included all the hatchery fry, do not form scales until their second summer. Fortunately it proved possible, by statistical treatment of the number of rings inside the first check, to differentiate between scales formed the first summer and scales formed the second summer, and thus to eliminate the danger of classifying a fish which had no first-year scale-growth as one year old at the first annual check when it was really at the end of its second year.

The results are shown in the following table:

GROWTH RATE

AVERAGE TOTAL LENGTH IN CENTIMETERS AT THE END OF EACH YEAR OF GROWTH:

| | 1 yr. | 2 yr. | 3 yr. | 4 yr. | 5 yr. |
|---|---|---|---|---|---|
| Lake 3 fish | 5.0 cm. | 12.7 cm. | 18.8 cm. | 20.8 cm. | 22.0 cm.* |
| Lake 4 fish | 4.1 cm. | 14.6 cm. | 22.9 cm. | 28.5 cm. | 29.4 cm. |

The Lake 3 averages were based on 123 fish, the Lake 4 averages on 147 fish. The difference between the two growth-rates, with Lake 4 fish smaller at the end of the first year but larger at the end of each succeeding year, holds good in a general way for the fish of the upper and lower systems. This difference is not hard to explain. Lakes 1, 2 and 3 have excellent natural spawning grounds, where the fish which escape the traps spawn early and the young have plenty of food. Lakes 4 and 5 have very poor natural spawning grounds, and must depend largely on fry planted from the hatchery for their replenishment. This explains the greater average size of the Lake 3 fry at the end of the first summer, and it explains why the scale analysis showed that 50% of the Lake 3 fish had formed scales in their first summer, whereas only 23% of the Lake 4 fish had done so.

Further, the lower lakes are much more densely populated than the upper, as shown by the count of fish in the spawning traps. The lower lakes have better protection for fry, and therefore probably higher survival. The lower lakes are not heavily fished, Lake 3 being

*Based on only four specimens.

closed. The upper lakes are heavily fished. The extreme contrast in population occurs between Lakes 3 and 4: with the same amount of water, Lake 3 furnished five times as many spawners in 1933 as did Lake 4.

The conditions in Lake 3, and to a less extent in Lakes 1 and 2, approach, therefore, the conditions in the South Fork of Kern and in Cottonwood Creek. A long-established natural balance results in a fish of small maximum size, the size of the individual being limited by the amount of food available for the whole population, hence the preponderance of six-inch fish in the creeks, of seven- to eight-inch fish in the lower lakes.

Whereas Lake 4, and to a less extent Lake 5, which yielded 50% more spawners from about the same amount of water, corresponds more nearly to a new-stocked barren lake where, in the absence of other competitors, there are not enough trout to consume the total available food, and growth is therefore not limited by that factor, hence, the attainment of a length of eleven to twelve, and up to fifteen inches, by the fish of these two lakes.

Of the other differences observed between the fish of various waters, the most conspicuous was the loss of parr marks by the fish of Lakes 4 and 5. This generally occurred before the assumption of the brilliant coloration typical of the mature golden trout, with the result that many of the fish taken by anglers on this lake, up to ten or even twelve inches in length, were silvery-grey fish with a rosy wash and no parr marks—not at all what is expected when fishing in water containing nothing but golden trout. All the fish observed in the lower lakes, in Cottonwood Creek, and in Golden Trout Creek and the South Fork of Kern, showed the parr marks regardless of age, indicating that the loss of these marks is in some way connected with rapid growth or large size, and the same phenomenon has been described for large lake-grown golden trout in other parts of the mountains.

Another conspicuous difference was that the meat of fish from the lakes was always pink, whereas that of fish from the creeks, whether Cottonwood below the falls, or South Fork of Kern, or Golden Trout, was always white. A more subtle difference was observed between the fish of Lakes 3 and 4 in the matter of longevity. In the former lake only 4 out of 115 spawners examined had reached the end of their fifth year, whereas in the latter about 33 out of 120 were at the end of their fifth year. This may be due to natural conditions, but it might also be due to differential planting of hatchery fry. A very much heavier planting in Lake 3 in 1929 than in the preceding year, for instance, would give an abnormally large proportion of four-year fish as compared to five-year fish in the spring of 1933.

In general, it may be said that five years is the normal span of life of the fish in Lake 4. The scale of one fish from Lake 4 indicated that it was spawning for the third time at the end of its sixth year

but, while other third-spawners were found, no other fish had surpassed the end of its fifth year. First spawning may occur at the end of either the third or fourth year, and the gonads are plainly visible the preceding summer.

With the help of and under the direction of Dr. Paul R. Needham, analyses were made of the stomach contents of fish from Lake 4. These were not extensive enough to warrant consideration in so brief a paper as this, but they showed conclusively that, for the summer season, the dominant items of food were caddis larvae and pupae, midge larvae and pupae, and cladocera.

The average weight of the fish was found to be proportional to the cube of the average length. For all fish measured, from all lakes, the equation $W = .0107\ L^3$ fitted the gram-centimeter averages very closely. Transposed into pounds and inches the equation reduces to $W = .000388\ L^3$, which gives an average condition factor of 38.8 in pounds and inches.

In closing, it might be of interest to consider further the question of species, without going in detail into the data which, like the rest of the data underlying this presentation, are set forth in the paper for which this material was originally collected.

*Salmo agua-bonita* Jordan, the inhabitant of the Cottonwood and of the South Fork of Kern water systems, is, according to Dr. Evermann's original report, to be distinguished from *Salmo roosevelti* of "Volcano" Creek principally by the extent of the spotting. In the former the black spots cover the sides of the body above the lateral line, whereas in the latter they are confined to the caudal peduncle. (They occur in both species on the dorsal, adipose and caudal fins.) Observation of the fish in the spawning traps showed specimens which fitted perfectly both of these descriptions, as well as specimens which furnished all degrees of intergradation between the two. The same was found to be true of the fish in Cottonwood Creek below the falls. The question seemed to merit further study, and trips were made to Mulkey Creek, to South Fork of Kern, and to Golden Trout Creek, all of which abound in small fish eager for any kind of lure. The specimens brought back showed that, while the *agua-bonita* type was predominant in the South Fork of Kern waters, and the *roosevelti* type predominant in Golden Trout Creek, fish of the other type were also present in each. Scale counts were then made, this being the only other definite, quantitative difference in the published descriptions of the two species, and statistical analysis showed no significant difference between all *roosevelti* and all *agua-bonita*. A difference was found between all Golden Trout Creek fish and all South Fork of Kern system fish which might possibly be significant, but as later counts showing much greater differences between fish in various parts of the Cottonwood Lakes proved that such differences could occur through the action of local conditions within a homogeneous stock, it seemed evident that they were no proof of difference of species. In fact,

analysis of all the scale counts indicated that in the golden trout this characteristic is not of such nature as to serve as a base for specific differences.

The problem here is further complicated by the fact that Golden Trout Creek and South Fork of Kern approach at one point to within a hundred yards of each other before turning and flowing off in opposite directions to fall into the Kern at widely separated points; by the fact that geological evidence indicates that they were once one stream; and by the fact that in 1883 they were joined by a man-made connection carrying enough water to permit fish to swim from one to the other. This connection had been broken before Dr. Evermann's visit in 1904, and has never been repaired.

Now, Dr. Evermann nowhere states that he found no *Salmo agua-bonita* in "Volcano" (Golden Trout) Creek and no *Salmo roosevelti* in South Fork of Kern. It seems probable that he found each to predominate in the stream which he assigned to it as habitat, and that he assumed that the fish of the other type had entered each stream through the man-made connection. But information is now available to us which was not available to him, namely that the fish of Cottonwood Creek and the Cottonwood Lakes include specimens with both types of marking, as well as intergrades. And the fish of Cottonwood Lakes descend from fish which were taken out of the South Fork of Kern in 1876, before the man-made connection existed. Which offers conclusive proof that the *roosevelti* type existed along with the *agua-bonita* type in the South Fork of Kern before man interfered, from which it may be conjectured that the same condition held in Golden Trout Creek.

It must be noted that all the above reasoning is based on the characters which have so far been used to distinguish the two species. It may be that anatomical differences exist which have not yet been brought to light. But it seems probable that, if Dr. Evermann were alive today and were making his exploratory investigation of the golden trout now, and that if he had access to all the information which is now available, he would, on the basis of the characters so far used, not set *Salmo roosevelti* off as a separate species, but would pronounce it a color variation or a subspecies of *Salmo agua-bonita* Jordan.

# AQUICULTURE AND AGRICULTURE

H. P. K. Agersborg

*Formerly Biologist, State of New Hampshire*

Agriculture of today gives better results than of yesterday. Modern methods in agriculture have demonstrated that cows, sheep, hogs, and fowl do better on certain foods than on others; that the cost of producing fodder poor in nutritive or growth values is equal to or greater than the cost of producing fodder rich in these qualities; that it costs more to raise and maintain a poor, non-productive cow or fowl than it costs to rear and maintain productive animals. It was found that this is a fundamental principle which holds for all types of domesticated beasts and fowl. Selective breeding, then, and selective feeding are fundamentals upon which modern agriculture rests.

To make aquiculture really successful, the same approach must be made to its problems. Completely successful aquiculture can only be possible by properly utilizing and by improving the natural waters, by improving methods at the hatcheries in the handling of fish, by developing a balanced fish food at the hatcheries and rearing stations, arrived at experimentally, by experimental feeding of select foods, and by experimental breeding of fish to attain high fecundity, high viability, and rapid growth on the least expensive food.

The carrying on of such fundamental studies in aquiculture can be done without additional cost to the state. With proper planning, it is quite possible to breed fish of a certain type, and to record how it was done; to keep and to hatch their eggs in separate troughs under proper flowage of water until hatched; when ready to feed to provide sufficient increase of water flowage, and to feed such fish according to a planned schedule, and on food of a given nature, according to a definite plan. This can be done along with the regular routine work without any extra cost in labor, equipment or food. Ultimately, only such fish should be bred as were found to give a better type fish, with reference to rapid growth in the shortest time on the least expensive food; with reference to low mortality, high fecundity, beauty, flavor, gaminess, and adaptability to waters of the state. Females with 3,000 eggs are to be preferred to those with only 800 or less, provided the fecundity and viability are at least equal or better amongst those of high prolificness. It ought to be possible to produce varieties of fish which possess all these desirable qualities. In order to obtain the capacity number of eggs for all the hatcheries in a state, it would

be necessary to care for only one-fifth as many breeders of such high prolificness.

New Hampshire had in 1933 a normal hatching capacity of less than 3,000,000 trout and salmon. We were keeping 10,000 brood fish of uncertain origin and of diverse value, without getting half the necessary number of eggs. One thousand brood fish of each sex and of the desirable prolificness could have given all the necessary eggs for our state. Eggs from selective brood fish can hardly be obtained as long as eggs are purchased promiscuously from out of state hatcheries; neither can selective brood fish be obtained even from fish reared in hatcheries in our own state as long as no distinction is made between prolific and non-prolific spawners, or between fish whose offspring are of low vitality or defective in some other way and those that are not. Non-prolific brood fish are costly organisms from the standpoint of artificial production as well as in the economy of propagation of the species in nature. Brood fish, of definitely known origin, fecundity, mortality during embryonic and post-embryonic development, age, growth-rate, form, color, and size in relation to food cost and age, should be kept separately. Fish showing the most desirable qualities should be promoted. They should be fed according to a definite plan, and for a definite purpose. They should be kept in a semi-wild state.

It should be realized that the male is just as important as the female in the attainment of the highest type fish according to the above mentioned qualities. When distinction is made between "dry" older males and the more "juicy" younger males, and in consequence of this, the older males are discarded early, one fails to realize that the older males are ripe in part and over a longer period than the younger males, a fact which could advantageously be made use of were it properly understood. Moreover, it may be quite possible to bring the older males to a more abrupt and complete ripeness, similar to young males, if they were fed on *certain foods* during the last two months (or longer) prior to the beginning of the spawning season. This is worth while trying. The effect on the species, of always breeding young males to females of all ages, is plain. It is the same as in animal husbandry, when similar breeding methods are used; the stock "runs out." This is just as necessary in acquiculture. Without such a plan of procedure, the cost in rearing fish will be as great as ever, the results, as poor as ever, and the people will continue to wonder why better results are not obtained for their investment.

Eggs, fry, fingerlings and older fish are often so crowded, far beyond their mechanical and physiological ability to endure, that if they do not die outright, they become defective, stunted, and deformed beyond their ability to recover. The amount of water necessary to keep older fish healthy depends on several things: (1) On the amount of flowage per minute. (2) On the size of the con-

finement or space or pool where the fish are kept. If the pool is relatively small, the amount of water flowing through this compartment should not be less than 10 gallons per minute for each 100 fish. (3) That the pool should be kept clean is of the greatest importance, especially in spring, during the changing of the season with oxygen change, increase in its consumption and less solubility due to the increase in temperature, and during summer with the attendant higher temperature. Growth and development cannot take place and the proper state of health be maintained in the absence of sufficient oxygen. Oxygen reduction below 5 in parts per million retards the metabolic activities, and growth and sexual development, which depend on normal metabolism, are checked and retarded. (4) As far as possible, salmonid fishes reared artificially, should always be allowed within the mean or medium temperature for the species. The maximum temperature range should be avoided because if the pH value (hydrogen ion concentration) should happen to jump, or be high in the first place, the acid reaction on the fish is much more deadly during the higher temperature range of the species than during the lower. In nature, the species can adjust itself by moving away from the unfavorable environment, not so in artificial confinements where they must take what is given to them, live through it or die.

It is obvious that the success in any business depends, in the largest measure, on the degree of observed facts; that without such observations and the intelligent understanding and use of them, the business in question cannot succeed. In fact, the "trial-and-error" method cannot long endure in today's competitive, social structure. Every successful farmer, of whatever kind, owes his success to the degree of his understanding of his particular problems, basic to the functioning of his work, and this he cannot have without observing the methods of his business, recording them, discarding the useless or too costly ones, and employing the best, the most productive ones.

There is no mystery connected with trout culture beyond the application of known biological principles. Since the fish culturist has nearly always been selected from amongst persons unfamiliar with the natural laws in general and biology in particular, fish culture in the United States still remains in a very primitive state. The fish culturist has kept the public misinformed in regard to the true status of his success. When more or less successful he has called it "luck," but he has not known why he has had luck, and so he has not been able to repeat the conditions which contributed to his partial success. The loss, which the state has suffered from the employment of untrained and improperly qualified workers in this highly important field of aquiculture, is much greater than the general public realizes. That a fish culturist of the "first order" should necessarily be one who has been allowed to waste, more or less,

thousands of dollars annually, in the improper attempt to rear trout, salmon and other game fish, all the time violating natural laws with the attendant result of *circa* 10 per cent instead of 100 per cent success is *ipso facto* quite sad amusement. The length of time this condition will be maintained depends on how long the actual facts on what has happened, and is happening, and how things might have been if scientific methods had been employed, are successfully kept from the ever hopeful, believing and good natured public.

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1933. Salient problems in the artificial rearing of salmonoid fishes, with special reference to intestinal fungisitosis and the cause of white-spot disease. Trans. Am. Fish. Soc., 63:240-250.

# A NEW METHOD AND APPARATUS FOR THE ACCURATE AND RAPID COUNTING OF FRY AND FINGERLINGS

GUSTAVE PREVOST

*Department of Public Works, Fish and Game, Quebec*

The problem of counting and sizing rapidly and accurately of fry and fingerlings has always been a difficult one for this Department. Inability to do so has been a source of embarrassment on more than one occasion. The methods of counting generally employed in hatcheries is usually unsatisfactory. Frequently they are merely estimated, a few counted into one can and the other cans filled approximately to the same extent. To count them all by hand is impossible for fry and impracticable for fingerlings. A better method and one that, I believe, in common use is to count by hand a small number of fish, weigh them and thus establish an index, and then weigh the remainder accordingly. This is a good method and has given satisfactory results. However, there is another method of counting fish and I think that it is an improvement upon the use of weights.

It is a question of employing the volume of the fish rather than their weights to determine their number. The principle involved is that the volume of water displaced by a body is equal to the volume of the body. Thus, if we know the volume of water displaced by a given number of fish, we know the average volume of each fish, as by weighing them we know the average weight. In practice I find that the volume method is not only more accurate but much quicker than weighing the fish. It is the purpose of this paper to describe the apparatus which I have designed to count fish volumetrically. This instrument consists of the following pieces: (1) a can of three-gallon capacity, having a bottom in the form of a cone, and a collar equipped with gaskets (rubber) and screw clamps to fit the tube, next described, and permit no leakage. (2) a long tube ending in a large funnel, all, as is the can, of galvanized iron. This tube is equipped with a gauge graduated in cubic centimetres. There is also a cock on this tube that, when opened, drains the water to zero on the gauge. It is usual to have two of these tubes to fit the same can. The smaller tube with a diameter of 1½ inch for fry, and a larger one with a diameter of 3 inch for fingerlings and older fishes.

Figure 1 shows the can with a tube attached. One can see the funnel of the tube as well as the cock, the gauge and the screw clamps. Figure 2 shows the tubes of different sizes unattached, with an ice strainer between them. Figure 3 gives all dimensions and details of this apparatus. In placing the fish in the funnel one uses a cotton hand net, or, better, an ice strainer, as the latter drains more quickly.

The apparatus is very easy to use and in practice is found to give very good results. The procedure is simple: (1) The tube is securely connected to the can by means of the screw clamps, the gaskets make the connection tight. (2) The gauge is adjusted to zero, i.e., the can and

FIGURE 1

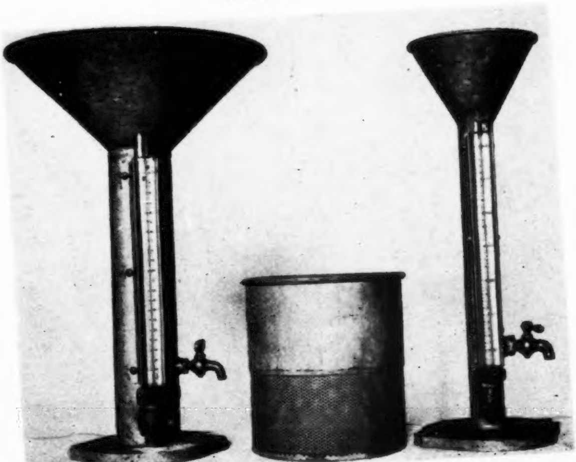

FIGURE 2

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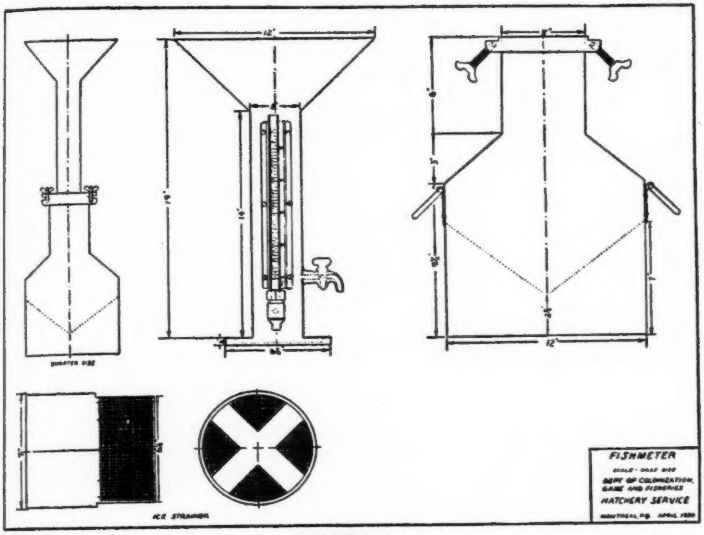


FIGURE 3

part of the tube is filled with water, the cock opened and the gauge then registers zero. (3) Count by hand any number of fish, usually one hundred, and place in the funnel, taking care to see that the fish are reasonably dry. If an ice strainer, such as shown in the photograph, is used, very little water will enter the tube, and, what is more important, it will be the same amount each time. (4) Read on the gauge the number of cubic centimetres that the water has risen. This gives directly the volume of the fish in c.c. It is easy to calculate from this the average volume of each fish, and the amount of water to be displaced for a desired number of fish. Once the water in the gauge has reached the highest mark, one has only to drain the gauge once more to zero and continue with the counting of fish. In this way, with the use of only one of these counters, large numbers of fish can be rapidly counted and poured directly from the counter to the distributing cans. The fish pour easily from the counter due to its cone-shaped bottom.

## Results

With fry or fingerling of equal sizes, or nearly so, the error involved in the use of this counter is very small, less than two per cent. However, we usually have to deal with fish that are variable in size, and in this case we do not wish to have the error any greater if possible. The following technique has generally been satisfactory. Count by hand fifty

Sheet 5.

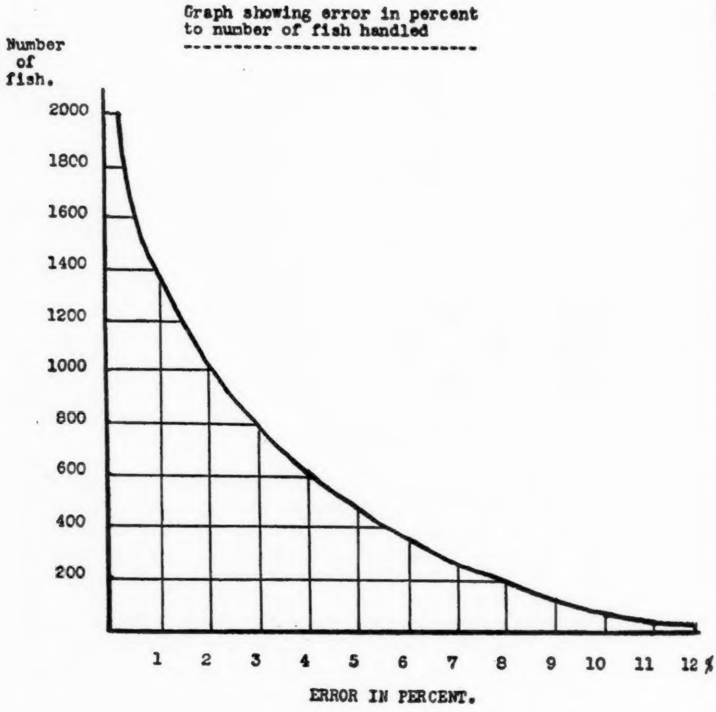


FIGURE 4

of the larger fish, i.e., those from the head of the trough, and then fifty from the bottom of the trough, i.e., the smaller fish. The total volume of these two lots of fish represent the average volume of a hundred fish from that trough. If the fish are in circular ponds, or other containers, it will be necessary to consider that fact in choosing the fish that are to be used as an index. The following table shows the probable error involved.

| Length of fish | Number counted by hand | Number determined by apparatus | Difference in numbers | Per cent error |
|---|---|---|---|---|
| 2 to 3 ins. | 73 | 83 | +10 | 12 |
| | 239 | 263 | +24 | 9 |
| | 322 | 331 | +9 | 3 |
| | 634 | 677 | +43 | +6.78 |
| | 305 | 285 | —20 | 6 |
| | 283 | 281 | +2 | 0.7 |
| | 283 | 281 | —2 | 0.7 |
| | 871 | 851 | —20 | —2.2 |

One sees from these figures that the smaller the number of fish involved the greater the error is likely to be. But that the total error in counting 1505 was plus 23, i.e., an error of 1.52 per cent, which is very small indeed.

## Advantages

The precision of the device described is no greater than that of a balance but the method is more rapid than weighing. The apparatus is more easily transported than a balance and is not affected by corrosion as weights might be. Using such a device the rate of growth of fish in the hatchery can be ascertained, the accuracy of counting in planting can be improved and the number of fish produced each year can be determined.

## Discussion

Mr. Deuel (New York): How large a fish can you measure with that apparatus?

Mr. Prevost: You can get a bigger can, if you like.

Mr. Deuel: If your fish varies, say from one inch to five or six inches you would have to have several different gauges?

Mr. Prevost: Oh, yes, you can get different gauges if you like.

Mr. Kingsbury: A few years ago an article appeared in Science by a man from the New York aquarium who used this displacement method for measuring small aquatic animals. It worked out very well, and from the paper that he prepared on the subject we thought it would be advisable to try it for measuring trout eggs. We did not have a very good technique, of course, and it did not work very well. This last spring I tried it on bass fry; I counted several samples and the thing seemed to be absolutely accurate. In one case of six hundred fish I had accurate results, but when we came to try two or three thousand fish, the percentage of error made the method inadvisable, the way I was trying to use it. It may be, however, the technique was not proper, but we measured absolutely the displacement of the amount of water we used—it did not make any difference because we took two readings each time.

Dr. MacKay (Ontario): In viewing the diagram of the apparatus, I was wondering if it would not be more convenient to have a piston arrangement in the upper part, so that the fish would not need to be transferred so inconveniently each time in the can. Instead of this arrangement, you would have a piston up the center that could be pushed down and the fish would drop down into the can. I think that would be more convenient.

# SELECTIVE BREEDING OF SPECKLED TROUT

K. G. SHILLINGTON

*Superintendent, Antigonish Hatchery, Nova Scotia*

Selective breeding of speckled trout at Antigonish Hatchery has five objectives: (1) Rapid growth; (2) Early maturity; (3) Large yield of ova; (4) Immunity to disease; (5) Short spawning season.

In the following, references are made to "Pond" stock and "Lochaber" stock. "Pond" stock signifies fish whose ancestry has been lost through many generations of hatchery reproduction. "Lochaber" stock indicates that their parentage is of the first or second generation of the wild speckled trout of Lochaber Lake in Antigonish County, Nova Scotia.

Satisfactory progress has been made in regard to objective No. 1 and the following statement shows a decided increase in the weight of the progeny of the second generation of selected Lochaber Lake fish over the first generation or progeny of the wild Lochaber Lake trout:

| Stock | Age of Fingerlings | Number of Fingerlings | Weight of Fingerlings |
|---|---|---|---|
| Pond (Selected) | 6.5 months | 100 | 50.5 ozs. |
| Pond (Not Selected) | 6.5 " | 100 | 33.5 " |
| Lochaber (2nd Generation) | 6.5 " | 100 | 19.5 " |
| Lochaber (1st Generation) | 7 " | 100 | 7.75 " |

The selected "Pond Stock" mentioned above refers to the brood fish which produced the fingerlings and not to the fingerlings themselves. These parent fish were the best of the early spawners chosen from 230 two-year-old fish. Their progeny, numbering 19,500, was of very even size. That of the other groups showed a great variation.

The quick early growth of the stock of selected breeders has not been carried through the later stages of their lives. In their third year, wild "Lochaber" stock had nearly caught up to the selected Pond stock in size. In their fourth year, the former exceeded the latter as shown below:

| Age | Stock | Average Weight |
|---|---|---|
| Yearlings | Pond | .46 lbs. |
| Yearlings | Lochaber 1st. Generation | .042 " |
| " | Lochaber 2nd. Generation | .17 " |
| Two-year-olds | Pond | .75 " |
| Two-year-olds | Lochaber 1st. Generation | .46 " |
| Three-year-olds | Pond | 1.06 " |
| Three-year-olds | Lochaber 1st. Generation | 1.00 " |
| Four-year-olds | Pond | 1.00 " |
| Four-year-olds | Lochaber 1st. Generation | 1.60 " |

Objective No. 3 has in part been reached. In 1933, three selected two-year-old females weighing nine pounds yielded 2,145, 2,242 and 2,340 ova, respectively, as against a yield of 872 per fish from average two-year-olds weighing six pounds. One three-year-old female weighing 1.25 pounds yielded 3,588 ova as against 1,260 from the average one-pound fish of the same age.

Not much progress has yet been made in regard to objective No. 4. Selected strains from stock that has survived many epidemics still appear very susceptible to them. This, however, does not apply to the wild stock first generation from Lochaber, which is far more resistant to them except in the case of thyroid tumor, which, on the other hand, has seldom been found in the Pond stock. An attempt to breed resistant strains is being continued. Epidemics occurring amongst the selected Pond stock from the yearlings and older groups tend to check the fishes growth, and it is possibly for this reason that the wild Lochaber stock exceeded the Pond stock in size in their fourth year.

In regard to objective No. 5, four groups of yearlings have been retained; each of these groups is the product of fish spawning on the same day selected for large yield and high percentage of fertility. They should spawn this fall. If heredity influences the spawning season, as found by Doctor H. S. Davis, the product of these groups should form a nucleus of a stock whose spawning will be so regulated as to greatly facilitate stripping operations.

# COPPER SULPHATE IN THE ELIMINATION OF COARSE FISH


JAMES CATT

*District Supervisor of Hatcheries, St. John, N. B.*


Where restocking trout waters by fry distribution is efficacious it is obviously more economic to do so than to use fingerlings or older fish. In many waters the increasing number of trout anglers has so upset the balance of fish population that fry can not longer be used as an effective restocking medium, commensurate with the results obtained. The question then arises whether to use fingerlings or larger fish or to eliminate predatory and competitor fish and stock with fry. In the former case the cost of rearing is heavy, but in the latter, angling and netting also proving costly, there remains the possibility of effectively and economically using poison. The objection to this method is that it destroys both game fish and food organisms indigenous to the water treated.

After considering various possibilities the Department of Fisheries for Canada decided to carry out a practical experiment using ordinary commercial copper sulphate ($CuSO_4$-$5H_2O$) as the eliminating agent in Lake Jesse, Yarmouth County, N. S. Having consulted the records of numerous authorities as to strength of copper sulphate solution necessary to kill various species of fish, preliminary experiments were carried out at Yarmouth Hatchery late in 1932 and early in 1933. The results were not satisfactory as the dosages proved too low. It was therefore thought that all the necessary factors had not been determined in the compilation of the records consulted. With this view it was decided to determine results by additional preliminary experiments using the water, and if possible the fish, from the lake selected for the final experiment. This was Jesse Lake on the headwaters of a branch of the Salmon River, Yarmouth County, Nova Scotia. It is roughly triangular in shape and is approximately 45 acres in area, with a maximum depth of 21½ feet, and an average depth of 8 feet.

The preliminary experiments, using Jesse Lake water and fish, were conducted as follows. In each case 62½ gallons (+) of solution was used.

June 16, 1933. Solution used: 1 part copper sulphate to 125,000 parts water.
Water temperature 73° (5 p. m.) and 62°F. (10 p. m.)
Seven yellow perch and one shiner introduced into solution.

| | |
|---|---|
| One perch and shiner died at | 6.30 p.m. |
| Two perch died at | 7.20 p.m. |
| All turned on backs | 7.50 p.m. |
| Two alive (turned over) | 9.20 p.m. |
| All dead | 10.30 p.m. |

During night, leeches, snails and caddisfly larvae died in solution.

June 17, 1933. Solution used: 1 part copper sulphate to 250,000 parts water.
Water temperature 59° (12.45 p. m.) and 57°F. (9.15 p. m.)

Two white perch and two yellow perch introduced into solution.
One yellow perch died at 1.00 p.m.
One white perch died at 1.20 p.m.
Second yellow perch died at 4.10 p.m.
Second white perch died at 9.15 p.m.

June 19, 1933. Solution used: 1 part copper sulphate to 500,000 parts water.
Water temperature 56° (10.45 a. m.) and 53°F. (9.50 p. m.)
Two white perch and three yellow perch introduced into solution.
First yellow perch died at 12.00 noon
Second yellow perch died at 2.00 p.m.
First white perch died at 5.15 p.m.
Third yellow perch died at 9.30 p.m.
Second white perch died at 9.50 p.m.

During the experiment the fish used varied in length from 6½ to 7 inches (white perch), and 4½ to 6 inches (yellow perch).

The pH of the water was: B.T.B. 6.1; B.C.P. 5.9.

Experiment continued:

July 5, 1933. Solution used: 1 part copper sulphate to 1,000,000 parts water.

Four yellow perch and three white perch introduced into solution. First fish died in 1 hour and last in 10 hours. All insect larvae, etc., died in 6 hours.

Solution used: 1 part copper sulphate to 2,000,000 parts water. Four white perch and three yellow perch.

All fish survived for 15 hours and at 24 hours only 1 dead.

From the foregoing it would appear that 1 part copper sulphate per million parts water was an approximately minimum lethal dose. However, as the survey was very rough and as a change in pH might occur in the water at any time it was decided to use about 3 parts per million, for the main experiment. As the lake was computed to hold about 980,100,000 lbs. of water, about 3,100 lbs. copper sulphate were required.

The main experiment was commenced August 3, 1934. Dr. M. W. Smith followed the experiment and collected scientific data before, during and after it. His complete report will be made available later, when the various collections have been examined. Dr. Smith found that practically all the phyto ÷ and zooplankton had been annihilated, but that the oxygen and bicarbonate contents, as well as the pH values, had changed but little. Most of the aquatic insects, clams, leeches, etc., also were killed.

A preliminary test to determine the most suitable kind of sack to use was made on August 2. The ordinary hessian bags for shipping salt, stock food, etc., of both coarse and fine weave all proved satisfactory. The finer weaves were finally selected in order to reduce the quantity of powdered copper sulphate that might quickly sift through the mesh of the coarser weaves and sink to the bottom before dissolving.

At 2.20 P. M. August 3, the process of poisoning the fish commenced. It was completed at 8 P. M. Four boats were used. They were fitted with outriggers from which sacks of copper sulphate were suspended, so that the upper end of each sack broke the surface. Each sack contained approximately 60 lbs. of copper sulphate. Owing to

a strong southerly gale and the fact that the boats were of widely varying types the original plan of traversing the lake from east to west had to be abandoned, and four boats in line abreast were run down wind from south to north. Three trips were made extending the whole length of the lake. Three additional trips were made covering the deep water at the north end. One trip carried out by two boats was made over the east bay, and bags were dragged by hand along the windward margin. As events showed, this marginal drag was not very efficient, for, although it was made in very shoal water within a few feet of shore, the solution flowed out to deeper water leaving an untreated zone, varying in width from a few inches to a few feet. By the morning of August 4 many fish, particularly catfish and eels, had moved into this zone. Accordingly, later the same day an additional drag was made along the absolute margin of the whole lake. This turned the fish back into deeper water, where, by this time, it is possible there was not a lethal dose of the compound in solution. From August 4 to August 8, inclusive, the dead fish were collected along the lake shores, sacked and sunk in the lake to act as fertilizer. They numbered tens of thousands. An estimate of the quantity and a classification of each species killed is being prepared by Dr. M. W. Smith.

On August 6 a large number of dead dragonfly larvae, chiefly *Gomphus* sp., as classified by Dr. Smith, were found at the south end of the lake. An apparently more resistant species, *Hagenius brevistylis,* was found dead and dying in large numbers along the east and south shores on August 11.

On August 9 many killifish, some scuds, young leeches and dragonfly larvae, all apparently healthy, were found in about one acre of shallow water near the outlet at the northwest corner of the lake. On August 10 many stonefly and some dragonfly larvae, apparently healthy, were found along the east shore.

From the night of August 8 to the morning of August 11, a 20 fathom gill net was kept set continuously, except for the time necessary to move it from the shoalest to the deepest part of the lake. The only capture made by it was 1 white perch, 10 inches long. On August 12 dying eels continued to move into marginal water. It is probable that they had encountered pockets of strong solution in the lake bottom.

On August 9 a number of food organisms, including several species of caddis and mayfly larvae, chirinomid larvae and small molluscs were obtained from Lake Annis, nearby. These were placed in Lake Jesse water. With the exception of some *Sphaerium* specimens they were all thriving on August 12. On the evening of the last mentioned date a considerable hatch of caddisfly was observed. As the larvae had proved easily killed by a copper sulphate solution it seems probable that the pupae cases are highly resistant to the treatment. Up to this date the emergent vegatation, including white and yellow water lilies, pickerel weed, *Scirpus* rushes, etc., did not appear affected.

## Conclusions

It is considered that so far as it has gone the experiment is a success. The numbers of fish killed and the lack of visible survivors, except for occasional individuals, indicates that their reduction approaches total elimination. A nucleus of food organisms remains, not only in the form of larvae, but also as images of dragonfly, mayfly, midge, etc.

The method of distributing the copper sulphate would be improved if,

(1) boats of a standard type and size were used;

(2) the courses taken by the fleet of boats were from windward to leeward in the form of a series of obtuse angled zigzags;

(3) during the latter part of a treatment the entire margin of the lake be sprayed with a very strong solution of copper sulphate.

Dr. Smith suggests that small motor pumps fitted up in the boats to pump the solution would probably permit of a quicker and more even treatment being applied to the whole area. This appears reasonable.

It is considered quite feasible to use the treatment economically on numbers of lakes of a size not exceeding 200 to 300 acres, providing, also, that they are relatively shoal. Only those lakes which are not fed by considerable waters containing enemy fish should be treated. The outlets, if any, of the selected lakes may be fairly well screened against the ascent of enemy and competitor fish (except eels) by the construction of low dams from the top of which screens made of parallel hardwood and iron rods extend down stream. These screens should be inclined slightly below the horizontal so that debris will be washed off whilst allowing the water to fall through them.

Should it develop from further investigations that the food supply in Jesse Lake is delayed in becoming reestablished there would be no great difficulty in augmenting it by replanting with caddisfly, stonefly and dragonfly larvae, etc., readily obtainable from nearby local sources.

As soon as it is determined that adequate food organisms are present in the lake, the process of restocking by the introduction of speckle trout fry will be commenced.

## Discussion

Mr. Rodd: In bodies of water such as Lake Jesse, where it is a practical matter to destroy the coarse predator fish by copper sulphate poisoning, the cost is very much smaller than the same work could be done in any other way. We have had some experience in trying to decrease the number of coarse fish by netting, but it is found that the cost runs up very quickly. By the use of the copper sulphate method the work is done all at once, and so far the expense has been comparatively small.

Mr. Terrell: I think we need more investigation as to the amount of copper sulphate that various aquatic plants will stand. From research and experiments

already carried out we know pretty well what amount of copper sulphate different fish will stand. We know that as a rule trout will die where a very weak solution of copper sulphate is used, and so will the suckers and carp, while members of the bass family, the black bass and the sunfish, will probably stand from ten to fifteen times as much copper sulphate as the trout will. This spring I had the experience of observing a body of water in Oklahoma, Lake Guthrie, that had been dosed with copper sulphate to keep the water supply clean and free from algae, but they have made the very serious mistake of using too much copper sulphate. They had killed practically all the plant life in the lake and had almost entirely depleted their fish supply, which had been very good. So I think we have to be very careful in the use of copper sulphate; and we should welcome any research that will tell us how much copper sulphate the different plants will stand and how much the different kinds of organisms the fish feed on will stand.

Dr. Davis: Chlorine gas is cheaper than copper sulphate and certainly is very effective; I think one part per million will kill all the coarse fish without any difficulty.

# RELATION OF TEMPERATURE TO THE INCUBATION PERIODS OF EGGS OF FOUR SPECIES OF TROUT

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## Historical

Stephen H. Ainsworth who experimented with trout in a little spring fed pond near West Bloomfield, New York, in 1859 was probably the first to offer a table showing the incubation periods of brook trout eggs in water of various temperatures. This table may be found on page 64 of "American Fish Culture" by Thaddeus Norris, published in 1868, and again on page 129 of Livingston Stone's "Domesticated Trout" (1872).

In a work entitled, "Trout Culture," 1870, Seth Green stated that "trout eggs will hatch in 50 days at a mean water temperature of 50° F., and for each degree colder or warmer five days more or less will be required, the difference, however, increasing the farther we recede from 50 degrees." This rule has been quoted widely in Europe as well as in America and probably was one of the earliest attempts to show the effects of temperature on the rate of development.

Wallich, 1900, after studying data from various federal salmon hatcheries in the west, concluded that the sum of the temperature units reckoned from the date of impregnation until hatching was constant at all temperatures normal to the eggs. A temperature unit was described as an increase of one degree above the freezing point of fresh water for a period of one day. Hence, if eggs required 50 days for development to the hatching stage at a mean daily temperature of 50° F., the sum of the temperature units would be $50 \times (50\text{-}32) = 900$.

This temperature unit theory used extensively by both botanists and zoologists was based on the belief that certain biological processes, including the development of eggs, could not take place at temperatures below the freezing point of water and that a definite quantity of heat would be required to bring a fertilized egg to a certain stage of development.

Reibisch (1902) showed that the sum of the temperature units in the case of cod and plaice eggs was not constant but increased regularly with increasing temperature. This was based on experiments conducted by Dannevig (1894), in which the eggs of cod were partly or wholly developed in sea water over a temperature range from —1 to +14 degrees C. Since the cod eggs actually developed to a certain stage at a temperature below the freezing point of fresh water, he

thought that the temperature units should be reckoned from some unknown point below zero, in fact, from the lowest point permitting development which he termed the "threshold temperature." This was determined by mathematical formula. After recalculating the temperature units from the new "threshold temperature" he obtained results which, though not constant, did not show a regular or wide variation.

One of the most interesting papers in this field was published in 1914 under the joint authorship of A. C. Johansen and A. Krough of the University of Copenhagen. They discuss in a favorable light the work of Reibisch mentioned above, without apparently passing judgment on its correctness. They also discuss the application of Van't Hoff's law to biological processess including the development of fish eggs. Quoting from these authors: "It has been customary to express the influence of the temperature upon the rate of biological processes in terms of Van't Hoff's law and it is almost universally assumed that such processes, when essentially of a chemical nature, follow this law."

Van't Hoff (1884) found by studying the velocity of certain chemical reactions over a comparatively long range of temperatures, that when the temperature was increased in algebraic progression, the reaction velocity was increased in geometrical progression.

It is only necessary to state here that Johansen and Krough, after applying the data of Dannevig on cod and plaice, found that they did not conform to Van't Hoff's formula but followed a much simpler one. Using the reciprocal of the number of days in the development period as an expression of the rate of development, they concluded that the rate of development of the eggs of cod and plaice was simply proportional to the increase in temperature instead of being a logarithmic function of the same as demanded of Van't Hoff's formula.

Since the appearance of Johansen and Krough's work several investigators have studied the effects of temperature upon the development of eggs of fresh water fishes and all papers that have come to the writer's notice have showed that this relationship over a normal temperature range conformed to Van't Hoff's law. Attention is called particularly to various papers from the Imperial Fisheries Institute of Tokio by Higurashi & Tauti, 1925; Kawajiri, 1927 and 1928; Nakai, 1926 and 1928; Kajiyama, 1929, and also to one by W. J. Crozier, 1926, who used a very complicated formula known as Arrhenius formula, to show the relation between temperature and rate of development.

In 1928 a well known English physiologist, J. Gray, in his admirable paper on the effects of temperature on the development of eggs of the European brown trout concluded that "the period of incubation is controlled by temperatures in a way essentially similar to that of other species" as determined by Crozier. However, on page 126 he offers a table for brown trout eggs derived from records supplied by owners of

various hatcheries purporting to show the "effect of constant temperatures on the time which elapses between the moment of fertilization and the time of hatching from the shell." There is a striking similarity between this table and the one put forth by Ainsworth and published in 1868. Both the temperature range and the number of days from fertilization to hatching are the same, excepting that Ainsworth used the Fahrenheit scale while Gray's temperatures are in Centigrade. Ainsworth's table is for American speckled trout, however, and in a letter to Thaddeus Norris he states that he estimated a little in the higher and lower figures as to the time of hatching, since his water did not hold at the temperatures indicated long enough to hatch the ova. Ainsworth's records are here presented in Table 1, as quoted from Norris' "American Fish Culture," page 64, 1868. Undoubtedly Professor Gray did not know of Ainsworth's table and it should be observed that the error does not in any way detract from the value of his conclusions since they refer to quite another matter.

TABLE 1. STEPHEN H. AINSWORTH TABLE SHOWING INCUBATION PERIODS FOR SPECKLED BROOK TROUT IN VARIOUS TEMPERATURES, QUOTED FROM PAGE 64 OF "AMERICAN FISH CULTURE" BY THADDEUS NORRIS, 1868

| Average temperature of water | Number days to hatching |
|---|---|
| 37° | 165 |
| 38½ | 135 |
| 39 | 121 |
| 40 1/5 | 109 |
| 41 | 103 |
| 42 1/3 | 96 |
| 431/3 | 89 |
| 44 | 81 |
| 45½ | 73 |
| 46½ | 65 |
| 48 | 56 |
| 50 | 47 |
| 52 | 38 |
| 54 | 32 |

## Experimentation

In the following pages I offer data which have been accumulating for a good many years on the incubation period of trout eggs over a wide range of temperatures. A few of the determinations were made at the U. S. Bureau of Fisheries Station, Cortland, N. Y. For others I am indebted to Superintendent Hayford of Hackettstown and Dr. Paul R. Needham. By far the greater number, however, have been experimentally determined in the Laboratory of Fish Culture at Cornell University in cooperation with the New York State Conservation Department.

In all cases the eggs were incubated in trays suspended in running water and not in closed vessels with periodic changes of water as was the case in the experiments of Johansen and Krough and the various Japanese investigators. Consequently, the water was not in all cases maintained at a constant temperature. Such fluctuations as were not brought about purposely, however, were very gradual.

Temperatures, in all cases, were taken with tested thermometers and during the past five years with chemical thermometers graduated to tenths of a degree. Records were made twice daily and from these the mean daily temperatures calculated.

The length of the incubation period was determined from the hour of impregnation to the average hatching date. Since the eggs were artificially impregnated, the beginning of the period was easily established. However, eggs from the same female impregnated at the same time did not all hatch on the same day, and it became necessary to count and remove the young to other trays as soon as they appeared. The day up to which one-half of the eggs had hatched was taken as the average hatching date and hence the end of the incubation period.

The lowest temperature records were obtained in the Cornell Hatching Station which is supplied with creek water showing temperatures near the freezing point from the middle of December until after the first of March. The range upward to 14 degrees Centigrade was brought about by passing small currents of creek water through Chromalox electric heaters of from 500 to 1,500 watts capacity or through the coil of a coal oil water heater. The latter method proved to be the more economical.

The cost of heating a continuous flow of water electrically was found to be very high. It was thus necessary to use as small a flow as possible consistent with a normal rate of development and a normal loss of eggs. Flows from one gallon down to one-fourth of a gallon per minute were sufficient in narrow hatching troughs 4 to 6 inches wide and two inches deep but, when used in standard troughs 14 inches wide and 6 inches deep, gave insufficient circulation through the eggs, resulting in a high mortality just prior to hatching.

Oxygen and carbon dioxide determinations were made frequently. In all cases in which the water was heated, the dissolved oxygen ran from a low of 6 ppm. to 11 ppm; the carbon dioxide never more than 2 ppm. Heating the water reduced slightly the amount of dissolved oxygen. This loss, however, was never more than 1 ppm.

In cases where the temperature was raised more than 5 degrees, the resulting fry were badly affected with gas bubble disease, which in this case was believed to be due to a super saturation of the water with nitrogen (Marsh and Gorham, 1905). This caused the sacs to become distended with gas, which resulted in the fry rising to the surface in a helpless manner. The condition was corrected, to a large extent, by passing the water over a series of baffles placed at the head of the trough. The eggs seem not to have been affected by the unnatural gas conditions.

Table 2 gives the average mean daily temperature of the water and incubation periods as determined for individual lots of eggs from brook, brown, rainbow and lake trout.

TABLE 2. INCUBATION PERIODS MEASURED FROM IMPREGNATION TO AVERAGE HATCHING DATE AS DETERMINED EXPERIMENTALLY FOR EGGS OF FOUR SPECIES OF TROUT

| Brook Trout | | Brown Trout | | Lake Trout | | Rainbow Trout | |
|---|---|---|---|---|---|---|---|
| Mean T.°C | Period (days) | Mean T.°C | Period (days) | Mean T.°C | Period (days) | Mean T.°C | Period (days) |
| 1.64 | 142.5 | 1.89 | 148.0 | 1.83 | 162.3 | 3.23 | 101.0 |
| 1.68 | 138.5 | 1.94 | 148.0 | 4.49 | 106.0 | 4.8 | 75.0 |
| 1.92 | 146.5 | 2.15 | 154.0 | 5.1 | 86.3 | 5.76 | 63.0 |
| 2.71 | 133.0 | 2.16 | 155.0 | 5.67 | 92.0 | 6.1 | 61.0 |
| 2.84 | 119.0 | 2.63 | 135.0 | 6.72 | 80.5 | 6.2 | 61.0 |
| 2.98 | 130.0 | 2.70 | 143.0 | 8.5 | 59.0 | 7.2 | 45.0 |
| 3.02 | 122.0 | 2.71 | 122.0 | 10.0 | 49.0 | 7.5 | 43.0 |
| 3.09 | 134.0 | 2.71 | 133.0 | | | 7.7 | 44.0 |
| 3.16 | 128.0 | 2.74 | 134.0 | | | 7.8 | 44.0 |
| 3.16 | 134.0 | 2.80 | 146.0 | | | 7.9 | 48.0 |
| 3.18 | 138.0 | 2.88 | 120.0 | | | 8.0 | 41.0 |
| 3.23 | 131.0 | 2.94 | 120.0 | | | 10.3 | 29.6 |
| 3.34 | 115.0 | 3.58 | 119.0 | | | 10.35 | 28.0 |
| 3.60 | 108.5 | 3.71 | 116.0 | | | 10.7 | 27.0 |
| 3.82 | 118.0 | 3.73 | 108.0 | | | 10.7 | 29.2 |
| 3.86 | 116.0 | 4.6 | 97.5 | | | 10.8 | 29.5 |
| 3.90 | 105.0 | 5.05 | 95.0 | | | 11.5 | 28.0 |
| 4.50 | 93.0 | 5.37 | 85.5 | | | 11.5 | 27.0 |
| 5.65 | 83.0 | 5.47 | 87.0 | | | 12.0 | 25.0 |
| 6.22 | 73.0 | 6.35 | 73.0 | | | 12.45 | 24.0 |
| 7.39 | 71.0 | 7.00 | 66.0 | | | 12.8 | 24.5 |
| 7.45 | 64.7 | 7.11 | 63.0 | | | 14.5 | 21.0 |
| 7.65 | 65.0 | 7.63 | 60.0 | | | 15.5 | 18.0 |
| 7.67 | 63.0 | 7.86 | 59.0 | | | | |
| 7.75 | 65.0 | 9.18 | 46.0 | | | | |
| 7.86 | 60.0 | 10.65 | 38.5 | | | | |
| 10.00 | 44.8 | 11.06 | 35.5 | | | | |
| 10.26 | 43.0 | 11.2 | 33.0 | | | | |
| 10.30 | 42.0 | 11.24 | 34.0 | | | | |
| 12.25 | 37.0 | | | | | | |
| 12.90 | 34.0 | | | | | | |
| 12.96 | 34.0 | | | | | | |
| 13.16 | 35.0 | | | | | | |
| 13.25 | 34.0 | | | | | | |
| 13.42 | 32.0 | | | | | | |
| 13.42 | 32.0 | | | | | | |
| 13.45 | 31.0 | | | | | | |
| 14.00* | 31.0 | | | | | | |
| 14.8 | 28.0 | | | | | | |

*Three determinations.

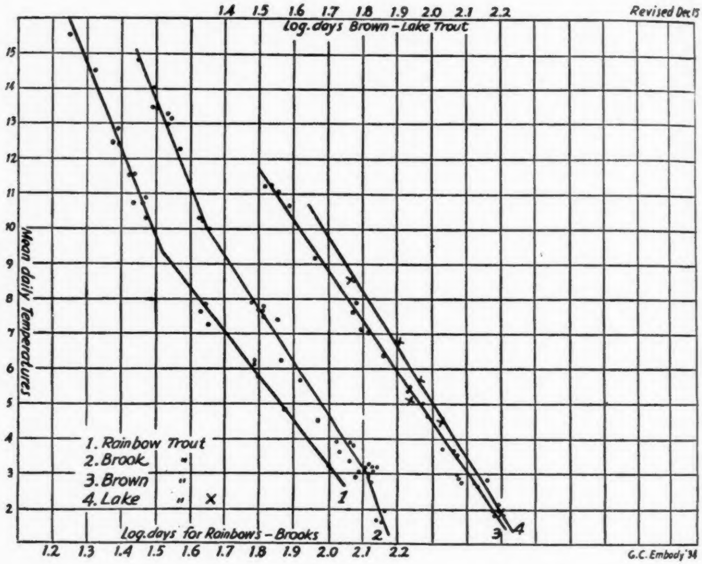
Using temperatures as abscissas and logarithms of the number of days constituting incubation periods, as ordinates, graphs (1) to (4) were constructed. These represent the mean relationship between temperature and incubation periods and facilitated the calculation of values recorded in Table 3.

The graphs for brown trout and lake trout are straight lines throughout the temperature range under experimentation. This is an indication that they conform to Van't Hoff's law and that development proceeds at a normal rate throughout this temperature range.

The graph for brook trout is a straight line having a definite slope between about 3° and 10° C. Beyond these points the slope changes abruptly, indicating a change in the rate of development. We must conclude that the rate taking place between 3° and 10° is normal and that temperatures below 3° and above 10° cause abnormal rates, abnormally rapid in the lower range and abnormally slow in the upper.

The graph for rainbow trout changes its slope between 9° and 10° C.

in a surprising manner and it is impossible to judge correctly what is the norm. We do know, however, from the experience of American fish culturists that the losses during incubation at the higher temperatures are no greater and in many cases are actually less than those at the lower temperatures. In the present experiments the losses in




temperatures below 6° C. were often so high that the determinations had to be discarded. In some cases, but not all, this may have been due to eggs of inferior quality. It happened, however, that the loss in the very highest temperature recorded (15.5° C.) was less than ten per cent.

In the Springville Utah State Hatchery, rainbow trout eggs are developed with only normal losses year after year at temperatures as high as 54° F. (12°+C.), and I understand that in certain federal hatcheries temperatures ranging above 60° F. (15.5°C.) give highly satisfactory results. Altogether, there is good reason to believe that temperatures above 7° to 8° will generally be more satisfactory with rainbow trout eggs than those below and for this reason I am inclined to consider the norm as located within the upper range between 9° and 16°C.

Kawajiri, 1927 (2) and 1928 developed rainbow trout eggs in cups of quiet water changing same daily. His losses were very high ranging

from 40 per cent at a temperature of 4.5°C. to 96 per cent at 11.3°C. However, one control lot developed in running water at 11.5°C. showed a loss of 40 per cent which was no greater than the minimum loss at 4.5°C. He thought the quality of the eggs accounted for the difference.

Few species show such a wide variation in the quality of the eggs as do our eastern domestic rainbows. They may have started as pure shasta rainbows, but now we find them badly mixed with Oregon steelheads and other races of the migratory steelhead-rainbow aggregation. In many cases where these hybrids are kept as breeders, the eggs are below standard. One must be certain of the quality of the eggs used before basing upon them any deductions as to the relation between temperature and viability.

TABLE 3. MEAN INCUBATION PERIODS FOR EGGS OF FOUR SPECIES OF TROUT WHEN THE VALUES FOR $Q_{10}$ APPROACH THE FOLLOWING:

| | | | | | |
|---|---|---|---|---|---|
| Brook trout | $Q_{10} = 4.58$ | between | 3° | and | 10°C. |
| | $= 2.29$ | between | 1.5° | and | 3° |
| | $= 2.52$ | between | 10° | and | 15° |
| Brown trout | $Q_{10} = 4.9$ | between | 2° | and | 11° |
| Lake trout | $Q_{10} = 4.24$ | between | 1.5° | and | 10° |
| Rainbow trout | $Q_{10} = 6.19$ | between | 3.0° | and | 9° |
| | $= 2.65$ | between | 9.0° | and | 15° |

| Brook trout | | Brown trout | | Lake trout | | Rainbow trout | |
|---|---|---|---|---|---|---|---|
| Mean T.°C | Period (days) | Mean T.°C | Period (days) | Mean T.°C | Period (days) | Mean T.°C | Period (days) |
| 1.5 | 146.0 | 1.5 | 160.4 | 1.5 | 166.0 | 3.5 | 103.5 |
| 2.0 | 140.0 | 2.0 | 148.0 | 2.0 | 155.0 | 4.0 | 86.3 |
| 3.0 | 129.0 | 3.0 | 127.2 | 3.0 | 134.0 | 5.0 | 72.0 |
| 4.0 | 110.5 | 4.0 | 107.7 | 4.0 | 116.0 | 6.0 | 60.0 |
| 5.0 | 94.4 | 5.0 | 92.0 | 5.0 | 100.0 | 7.0 | 50.0 |
| 6.0 | 81.7 | 6.0 | 78.5 | 6.0 | 87.1 | 8.0 | 41.7 |
| 7.0 | 70.0 | 7.0 | 66.8 | 7.0 | 75.0 | 9.0 | 34.7 |
| 8.0 | 60.0 | 8.0 | 57.0 | 8.0 | 65.1 | 10.0 | 30.8 |
| 9.0 | 51.5 | 9.0 | 48.6 | 9.0 | 56.2 | 11.0 | 28.2 |
| 10.0 | 44.4 | 10.0 | 41.4 | 10.0 | 49.0 | 12.0 | 25.6 |
| 11.0 | 40.3 | 11.0 | 35.4 | | | 13.0 | 23.3 |
| 12.0 | 36.7 | 11.5 | 32.7 | | | 14.0 | 21.2 |
| 13.0 | 33.5 | | | | | 15.0 | 19.3 |
| 14.0 | 30.6 | | | | | 16.0 | 18.4 |
| 15.0 | 28.0 | | | | | | |

## Mathematical Relation of Temperature to Rate of Development

The mathematical relationship between temperature and the incubation period may be shown by means of the Arrhenius formula as follows:

$$Q_{10} = \left(\frac{T_2}{T_1}\right)^{\frac{10}{\theta_1 - \theta_2}}$$

$Q_{10}$ is a constant representing the change in the rate of development over an increment of ten degrees.

$\theta_1$ and $\theta_2$ are any two temperatures in which development may take place.

$T_1$ and $T_2$ represent the periods in days corresponding to temperatures $\theta_1$ and $\theta_2$.

Substituting different combinations of values in Table 3, the average calculated values of $Q_{10}$ for the four species of trout approximate the following:

| | | | | | |
|---|---|---|---|---|---|
| Brook trout | $Q_{10} =$ | 4.58 between | 3° | and | 10.2°C |
| | $=$ | 2.29 between | 1.5° | and | 3° |
| | $=$ | 2.52 between | 10° | and | 13° |
| Brown trout | $Q_{10} =$ | 4.9 between | 2° | and | 11° |
| Lake trout | $Q_{10} =$ | 4.24 between | 1.5° | and | 10° |
| Rainbow trout | $Q_{10} =$ | 6.19 between | 3.0° | and | 8° |
| | $=$ | 2.65 between | 10.0° | and | 15° |

Kawajiri, 1928, calculated the value of $Q_{10}$ for rainbow trout to be 4.6 over a temperature range from 4.5° to 11.3°C. I have not been able to find similar calculations by others for brook, brown or lake trout.

## Variation in the Period of Incubation

It should be emphasized that the periods recorded in Table 3 are approximate mean values determined from the hour of impregnation to the average hatching date and with eggs from different strains of domestic trout, except in the case of lake trout. These last came from a mixture of eggs of wild breeders taken from Raquette Lake, New York, and as one might expect, the data obtained conform more closely with the straight line relation between temperature and period, than is the case with the other three species. The one set of values farthest out of line (5.1°C.—86.3 days) was obtained from a single lot purposely developed in a very low temperature until well eyed and then plunged immediately into water about eight degrees warmer. This action shortened the period by about eleven days.

There is great variation even among the eggs from the same individual, which is indicated by the fact that all eggs from one female though fertilized at the same time hatch out over a considerable period of time. This actual hatching period may vary from 3 to 4 days in high temperatures to 15 or 20 days in very low temperatures (Table 4).

TABLE 4. SHOWING RELATION OF TEMPERATURE TO THE LENGTH OF THE HATCHING PERIOD FOR EGGS OF RAINBOW TROUT

| Water temperature O°C | Hatching period (days) | Number eggs hatched |
|---|---|---|
| 5.7 | 14 | 394 |
| 8.2 | 8 | 188 |
| 12.9 | 6 | 896 |
| 17.6 | 3 | 600 |

There is also variation in lots of eggs of different individuals of the same strain. Two lots of approximately 700 eggs from each of two females of the Hayford strain of brook trout were fertilized by the same male at the same time and incubated in adjacent compartments of the same tray, immersed in the same water. Conditions were as nearly

alike as could be brought about and yet at a temperature of 3.16°C. one lot hatched in 128 days while the other required 134 days. Here is a difference of 6 days amounting to about 2.3 per cent from the mean.

Variations in the length of the period by as much or even more than ± 4 per cent from the mean may be expected in eggs of the various strains of domestic breeders held in hatcheries.

A case in point consisted of two lots of brown trout eggs, one from a female of the Hayford strain, the other from a Caledonia female of same age. These were fertilized at the same time, incubated in adjacent compartments of the same tray in water having a mean daily temperature of 2.7°. The incubation periods were 122 days for the first lot and 133 days for the other, a difference of eleven days or about ± 4.3 per cent from the mean.

## Summary

1. Stephen H. Ainsworth and Seth Green were probably the first to offer a table and a rule showing the relation between temperature and the incubation period of fish eggs.

2. Wallich attempted to show that the sum of the temperature units was constant at all temperatures normal to eggs.

3. Reibisch showed that this temperature unit sum was not constant in the case of cod and plaice eggs if reckoned from the freezing point of fresh water, but concluded that if some "threshold temperature" below zero were used, these sums should be constant.

4. Johansen and Krough concluded that the rate of development of eggs of cod and plaice was simply proportional to the increase in temperature.

5. Other investigators, including several Japanese, subsequently proved that the relation between temperature and rate of development followed very closely Van't Hoff's Law.

6. In the present experiments eggs of brook, brown, rainbow and lake trout were incubated in running water over a wide range of temperatures. The incubation period in each case was determined from the time of impregnation until the average hatching date. Semi logarithmic graphs were plotted and from these the mean values for the incubation periods were determined.

7. The straight line character of each graph indicates conformity with Van't Hoff's Law.

8. The graphs for brown and lake trout indicate a normal rate of development over the temperature range studied.

9. The graphs for brook and rainbow trout indicate changes from the normal rate of development over a part of the range studied. Development was abnormally slow in the higher temperatures and abnormally rapid in the lower temperatures.

10. In the case of rainbow trout the rate changes at some place between 9 and 10°C.

11. The Arrhenius formula was used for the calculation of the temperature constant, $Q_{10}$.

12. Variations in the rate of development were noted among eggs from the same female; among eggs from different females of the same strain and among those from different females of different strains.

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## Discussion

Mr. Langlois: I am wondering if the author or his substitute, or Dr. Greeley, can tell me how long it takes the female brown trout spawning naturally to become spent.

Dr. Greeley: I cannot answer that question except possibly by analogy with the other species of trout, which may be worth something, because in that respect I think they are very much the same. I have watched a female brook trout for a period of several days, during which she was digging several places successively upstream. I believe the number of nests dug by any one fish and the amount of time taken to spawn out would vary a good deal with the size and age of the fish. We tagged quite a few brook trout on the spawning grounds, and they remained right up in the spring creeks for a long time, as much as twenty days, both males and females. I have never, however, been able to follow individual trout long enough to determine that question.

Mr. Langlois: I wondered whether it was possible that differences in the incubation period might be explained by the differences in the date at which the eggs would naturally be extruded by the female.

Dr. Greeley: There may be a point there. The eggs taken from any one

female may vary a little bit in the particular stage that they have reached at the time they are taken. I think it is possible that some of the eggs taken in stripping might be at a stage where they would have a little jump on some of the others. At extremes, of course, you get green eggs which are not capable of hatching.

Dr. Belding: I think we have been perhaps a little wrong in determining the difference in spawning season and the time of incubation by comparing different hatcheries—and this does not apply to the paper prepared by Dr. Embody with respect to work done under control conditions. I was just going to call attention to some of the factors noted in certain observations on which Mr. Rodd and I made a report years ago in regard to the incubation of the salmon egg in the different hatcheries of the Dominion.

We found a difference in time of incubation, but it did not correlate with the temperature within certain ranges. When you got extremely cold water on the one hand there was a very marked difference, although our greatest extreme was roughly ninety days as against one hundred and eighty-seven days. There was very definite evidence of temperature factor in those two extreme cases, but in the average run where there was not so much difference in temperature we did not find any real correlation between them, because of the different factors that came in; and I am going to mention some of these to show you how complicated the problem is.

First is the question of season. If, for instance, in some Nova Scotia hatcheries there was a very marked difference in the rapidity or shortness of time of incubation, although the temperatures ran about the same, that I would call "season." Then in all probability range of temperatures made a great deal of difference, because you would have a mean temperature in one hatchery the same as that of another, and yet the ranges would be quite different. Likewise changes in temperature varied in the different hatcheries during the period of incubation, and a high temperature at some crucial period in incubation undoubtedly was a great deal more important than at any other period of the incubation. Other factors entered into the matter, such as the flow of water, the size of the trough, and so on, in the particular hatchery concerned. And finally the question of heredity in the particular strain of salmon eggs from the different rivers also made a striking difference. I merely call attention to these factors to show that it is almost impossible to compare incubation periods in one hatchery with those in another.

# COMPARISON OF LABORATORY AND PRACTICAL TESTS FOR DETERMINING THE NUTRITIVE VALUE OF FISH MEALS*

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## Introductory

Fish meals are widely used in the feeding of domestic animals, particularly poultry. They are fed primarily as a protein concentrate, but are considered to have additional virtues as valuable sources of calcium, phosphorus and other minerals, iodine, vitamin G and sometimes vitamins A and D. Manning,[1] DeLisle,[2] and Woodman[3] have published excellent bibliographies dealing with the uses and value of fish meals in animal feeding.

In 1933 the total production of fish meal in the United States and Alaska was approximately 90,000 tons valued at $2,700,000.[4] Inasmuch as an additional 20,000 tons is imported annually, we reach a very large total of this product which is consumed very largely by domestic fowls and animals. This investigation deals only with the meals manufactured from "ground fish" and which are known to the trade as "white fish meals." These meals make up about 12 per cent of the total tonnage, but are considered to be of superior physical quality and nutritive value.

Several types of white fish meals are available, each type depending largely upon the method of manufacture and the nature of the raw material, i. e., gurry, fillet or salt-fish waste, skins, etc. The three principal methods of manufacture are flame, vacuum and steam drying. All three methods are extensively used, though very often the consumer of the fish meal is unaware of the particular method of manufacture employed or the source of the raw material. In vacuum drying the temperature of the meal does not greatly exceed 100° F., in steam drying it is approximately 300°, and in flame drying the temperature may momentarily reach 1,000° F. Several investigators have reported findings which show the vacuum-dried fish meals to be somewhat superior nutritionally to the flame dried for domestic animals and rats. The actual chemical composition is practically the same. It seems probable that excessive heat has a detrimental effect upon the protein. In fact Morgan and Kern[5], as well as Invaldsen[6], observed that temperatures above 383° F. partially destroyed certain essential amino acids of meat proteins. Thus the inferior biological value of the flame-dried meals may be explained.

About 50 per cent of the total tonnage of white fish meals is extracted with hot water for glue extraction. The residual meal contains only the water-insoluble constituents as compared with the

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unextracted product, which contains the water soluble portion as well. While it is reasonable to suppose that nutritive differences exist in these two types of meal, little research has been conducted on this subject. It was the purpose of this investigation to determine if possible what differences in nutritive value exist among (1) the types of raw materials such as gurry, waste and skins, (2) flame and vacuum-dried fish meals, and (3) extracted and non-extracted meals. All the results will not be reported in this paper, which is to be considered as a preliminary contribution. We shall point out briefly how the method of evaluating the fish meals may affect the conclusions, and incidentally shall present certain data on the vacuum versus flame dried and extracted versus non-extracted fish meals.

The conclusions reached by previous investigators as to the value of certain fish meals have been based either on feeding white rats a ration in which fish meal constituted the sole source of protein, or on feeding experiments with growing chicks or laying hens where fish meal supplemented grain. Of course other workers have also investigated the supplemental feeding value for rats, swine and cattle. Since fully 90 per cent of the edible fish meals produced in this country are used for feeding poultry, our interest is particularly with that of the poultryman. As matters now stand poultrymen are unable to conclude, as a result of the conflicting claims of the various fish meal manufacturers and feed salesmen, whether one fish meal is actually worth more than another for chick growth or egg production. Since it requires less time, and is far less costly, many rat experiments have been made. On the other hand, many of the poultry feeding experiments have been poorly planned and the results are not statistically reliable. The usual fault has been use of too few birds and presence of several uncontrolled variables. A properly conducted poultry feeding experiment requires very careful planning, control of every possible variable which might influence results, and a large number of birds fed over a considerable period of time. It is only by applying statistical methods to the data thus obtained that accurate deductions can be reached.

## Samples

The samples were specially manufactured at a plant in Gloucester, Massachusetts, under careful supervision, in order to insure their integrity. Ground fish (white fish) meals were manufactured by the flame-drying and vacuum-drying methods from fresh gurry, waste and skins. These samples were in turn subdivided into extracted and non-extracted meals. In this paper four waste meals and one mixed (gurry and waste) are considered. Several hundred pounds of each lot of fish meal were prepared. The writers are much indebted to the U. S. Bureau of Fisheries Technological Laboratory at Gloucester for vacuum drying and grinding most of the samples. Chemical analyses of the samples are given in Table 1.

**TABLE 1. COMPOSITION OF FISH MEAL SAMPLES**

| | Samples | | | | |
|---|---|---|---|---|---|
| Constituent | Vacuum Dried Waste No. 1 | Extracted Waste Vacuum Dried No. 2 | Extracted Waste Vacuum Dried No. 3 | Extracted Flame Dried Waste No. 4 | Non-extd. Vac. Dried Gurry and Waste No. 5 |
| | Per cent | Per cent | Per cent | Per cent | Per cent |
| Moisture | 5.23 | 2.48 | 3.25 | 3.08 | 8.53 |
| Protein | 62.94 | 54.38 | 46.54 | 52.00 | 63.94 |
| Fat | 0.43 | 1.05 | 1.11 | 1.93 | 3.67 |
| Ash | 31.65 | 39.86 | 47.35 | 38.61 | 21.50 |
| Calcium | 10.69 | 14.07 | 16.64 | 13.16 | 7.36 |
| Per cent Calcium phosphate equiv. to Ca | 27.58 | 36.32 | 42.30 | 33.98 | 18.98 |
| Phosphorus | 5.84 | 7.30 | 8.80 | 6.63 | 3.96 |
| Per cent calcium phosphate equiv. to P | 29.20 | 36.50 | 44.00 | 33.15 | 19.80 |
| Ratio of Ca to P | 1.83:1 | 1.93:1 | 1.89:1 | 1.98:1 | 1.86:1 |

## Fish Meal as a Sole Source of Protein for Growing Rats

The experiment was patterned after the work of McCollum and Daniel[7], who studied several fish meals by this method. We were forced, however, to substitute starch for dextrin as an energy source in this ration in order to keep the rats in good health. The starch was treated with wheat germ extract and contained 1.4 per cent protein. The fish meal incorporated in the ration was the only source of protein, aside from the very small amount in the treated starch. Casein controls were used, where this food served as the sole source of protein in the ration at the 9 and 15 per cent levels. Thus, we have a comparison of the relative value of casein (dry skim milk) and fish meal for rats.

Two sets of rations were used, the first or "A" series (See Table 2),

**TABLE 2. FORMULAE FOR RAT RATIONS**

Ingredients in all rations:

| | |
|---|---|
| Salt mixture | 2.9 per cent |
| Cod liver oil | 2.0 per cent |
| Agar | 2.0 per cent |
| Treated starch | 12.0 per cent |
| Total | 18.9 per cent |

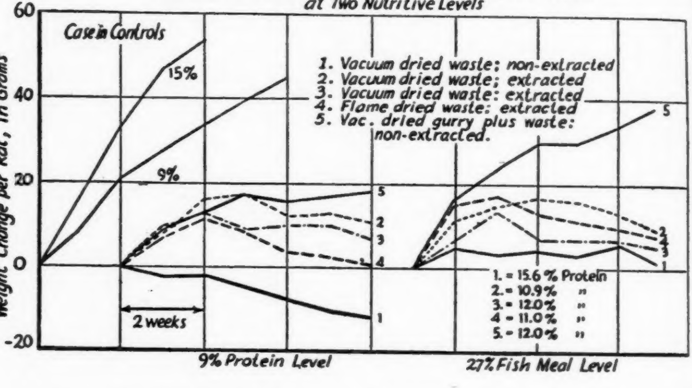
**FORMULAE FOR THE VARIABLE 81.1 PER CENT PORTION OF RAT RATIONS CONTAINING FISH MEAL AS A SOLE SOURCE OF PROTEIN**

| | Fish Meal Constituents | | | | Calorific | Variables |
|---|---|---|---|---|---|---|
| Sample | Ration No. | Per cent Fish Meal | Per cent Fish Meal Protein | Per c't Fish Meal Ash | Per cent Untreated Starch | Per cent Butter Oil |
| 1 | A | 15.60 | 9.00 | 5.39 | 59.90 | 5.60 |
| 2 | A | 22.24 | 9.00 | 10.86 | 48.26 | 10.60 |
| 3 | A | 20.30 | 9.00 | 9.25 | 51.90 | 8.90 |
| 4 | A | 22.05 | 9.00 | 10.38 | 48.65 | 10.40 |
| 5 | A | 14.18 | 9.00 | 3.04 | 63.31 | 3.63 |
| 1 | B | 27.00 | 15.58 | 9.33 | 44.80 | 9.30 |
| 2 | B | 27.00 | 10.92 | 13.20 | 41.40 | 12.70 |
| 3 | B | 27.00 | 11.96 | 12.30 | 42.35 | 11.75 |
| 4 | B | 27.00 | 11.02 | 12.71 | 41.50 | 12.60 |
| 5 | C | 18.89 | 12.00 | 4.06 | 57.54 | 4.67 |

where the protein level was maintained at exactly 9 per cent; and in the "B" series, where equal percentages, e. g., 27 per cent, of the several fish meals were incorporated in each ration. This latter experiment thus compares the relative weight for weight value of the different fish meals.

Sixty young rats, 30 male and 30 female, were divided into 10 groups of 6 each of equal weight and sex distribution, and placed on the 10 rations described in Table 2. The rats were individually caged. The ration was weighed out daily to determine the amount consumed, care being taken to prevent losses. The rats were weighed weekly and the experiment continued for 6 weeks. The essential data are reproduced in Figure 1 in the form of graphs so as to facilitate comparisons. Each curve represents the average gain or loss in weight of the 6 rats on each ration.

Figure 1 Comparative Growth of Rats fed Casein and Five Fish Meals as Sole Sources of Protein at Two Nutritive Levels




An inspection of Figure 1 shows that, while none of the fish meals approached casein in nutritive value, the three extracted waste meals were considerably superior to the non-extracted sample at both levels. The non-extracted mixed meal (gurry and waste) was somewhat superior to any of the waste meals when fed at the same levels. The extracted, flame-dried sample was distinctly inferior to the extracted, vacuum-dried meal. At neither the 9 per cent protein level nor the 27 per cent fish meal level did any sample except the casein and mixed meal (Sample 5) show normal growth curves for the rats. However, nutritionists usually agree that a maintenance or slightly higher level gives a better basis of comparison for foods than adequate levels. The superiority of casein over fish meals for rat growth is clearly demonstrated. It is apparent that as sole sources of protein for growing

rats, these fish meals, at the protein levels used, are nutritionally inadequate.

## Fish Meal as a Supplementary Source of Protein for Growing Chicks

This experiment was designed to test in a practical fashion simulating as closely as possible the manner in which fish meals are actually used by the poultryman in the raising of chickens. For this purpose a modification of the New England College Conference Chick Mash (see Table 3) was used, as this formula is widely used by New England poultrymen. The formula was changed by adding additional fish meal in place of meat scrap. (Two-thirds as much fish meal by weight was used as meat scrap.) Since slipped tendons may develop in battery-bred chicks receiving over 0.7-0.8 per cent phosphorus in the ration, care had to be exercised not to feed too much fish meal. The same samples of fish meals were used in this experiment as were used for feeding rats previously. The calcium and phosphorus contents of the chick mash which was fed at age 2-12 days were 2.50 and 1.19 respectively; for the revised test mash fed at age 12-26 days, 2.02 and 0.927 (average), and for the test "All Mash" fed at age 26-82 days, 1.48 and 0.756 per cent (average) respectively. In spite of care in computing these rations, a slight excess of phosphorus was present and accounts for the appearance of some slip-tendon disease in our chicks.

TABLE 3. FORMULAE FOR MASH RATIONS USED IN CHICKEN EXPERIMENT SHOWING THEIR RELATIONSHIP TO THE N. E. COLLEGE CONFERENCE CHICK MASH FORMULAE

| N. E. College Conference Chick Mash Formula (Fed age 2-12 days) | Revised Chick Mash Formula (Fed age 12-26 days) | Chick "All Mash" Formula (Fed age 26-82 days) | % Comp. N. E. C. C. Mash | % Comp. Revised Mash | % Comp. Chick "All Mash" |
|---|---|---|---|---|---|
| 200 lbs. corn meal | same | same | 29.54 | 30.67 | 20.45 |
| 100 lbs. oat groats (or gr. oats) | 100 lbs. gr.oats | same | 14.77 | 15.34 | 10.23 |
| 100 lbs. bran | same | same | 14.77 | 15.34 | 10.23 |
| 100 lbs. middlings | same | same | 14.77 | 15.34 | 10.23 |
| 50 lbs. meat scrap } 25 lbs. fish meal } | 50 lbs. fish ml. or fish meal & sand | same | 7.39 } 3.69 } | 7.67 | 5.11 |
| 50 lbs. dr'd sk. milk | same | same | 7.39 | 7.67 | 5.11 |
| 25 lbs. alfalfa meal | same | same | 3.70 | 3.83 | 2.56 |
| 15 lbs. gr. limestone | same | same | 2.21 | 2.30 | 1.53 |
| 5 lbs. salt | same | same | .74 | .77 | .51 |
| 7 lbs. cod liver oil | same | same | 1.03 | 1.07 | .71 |
| | | 326 lbs. corn m. | — | — | 33.33 |
| 677 lbs. Total | 652 lbs. Total | 978 lbs. Total | 100.00 | 100.00 | 100.00 |

Five hundred Rhode Island Red baby chicks were carefully sorted out from a large hatch and assembled into 10 groups of 50 chicks each. Weight distributions in each lot were almost identical. All chicks were wing-banded and placed in battery brooders heated by thermostatically controlled electric hovers. The mash fed all chicks up to 26 days old contained 3.57 per cent fish meal protein; the ration after that age contained 2.38 per cent. The chicks were weighed indi-

TABLE 4. PROXIMATE ANALYSIS OF RATIONS FOR CHICKEN GROWTH EXPERIMENTS

| | N. E. C. C. Mash Fed All Chicks Age 2-12 Days | Revised Test Mashes Fed Age 12-26 Days | | | | | "All Mash" Rations Fed Age 26-82 Days* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. 1* | No. 2 | No. 3 | No. 4 | No. 5 | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| Per cent Moisture | 7.53 | 10.07 | 10.37 | 9.16 | 10.25 | 19.86 | 10.70 | 11.30 | 10.10 | 10.90 | 10.50 |
| Per cent Nitrogen-free Extract | 54.19 | 54.92 | 54.67 | 55.62 | 55.38 | 55.36 | 60.09 | 60.06 | 60.36 | 60.69 | 60.13 |
| Per cent Fiber | 3.55 | 4.20 | 4.36 | 4.14 | 4.42 | 4.16 | 3.43 | 3.37 | 3.50 | 4.47 | 3.31 |
| Per cent Fat | 5.85 | 4.44 | 4.48 | 4.61 | 4.38 | 4.67 | 4.40 | 4.10 | 4.57 | 4.17 | 4.66 |
| Per cent Fish Meal Protein | ---- | 3.57 | 3.57 | 3.57 | 3.57 | 3.57 | 2.38 | 2.38 | 2.38 | 2.38 | 2.38 |
| Per cent Grain and Milk Protein | ---- | 13.16 | 13.16 | 13.38 | 12.98 | 13.07 | 11.98 | 12.07 | 12.16 | 11.90 | 12.22 |
| Per cent Total Protein | 19.84 | 16.73 | 16.73 | 16.95 | 16.55 | 16.64 | 14.36 | 14.45 | 14.54 | 14.28 | 14.60 |
| Per cent Fish Meal Ash** | ---- | 1.80 | 2.62 | 3.63 | 2.65 | 1.29 | 1.20 | 1.74 | 2.42 | 1.77 | 0.86 |
| Per cent Sand | ---- | 2.00 | 1.10 | 0.00 | 0.81 | 2.09 | 1.33 | 0.74 | 0.00 | 0.54 | 1.39 |
| Per cent Grain and Milk Ash | ---- | 2.77 | 2.60 | 2.82 | 2.49 | 2.86 | 2.45 | 2.20 | 2.47 | 2.14 | 2.51 |
| Per cent Limestone | 3.73 | 2.30 | 2.30 | 2.30 | 2.30 | 2.30 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 |
| Per cent Salt | 1.24 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 |
| Per cent Total Ash | 9.04 | 9.64 | 9.39 | 9.52 | 9.02 | 9.31 | 7.02 | 6.72 | 6.93 | 6.49 | 6.80 |

*Numbered after fish meals contained in the mashes.
**Calculated from fish meal analyses.

vidually at 7 day intervals throughout the experiment. Pigmentation, feather development, feed consumption, freedom from slip-tendon or other disease, were also observed at weekly intervals. Tibiae of 3 chicks on each ration were taken for measurements and analysis on the twenty-eighth day and at the termination of the experiment. After the twenty-sixth day the chicks in the various lots were transferred to heated pens and were given access to a small yard. At the age of 54 days the distribution of birds in each two pens on a single ration was changed. The males were segregated in one pen and the females in another in order to differentiate between weight variations due to sex. Since each bird was wing-tagged, it was not difficult to go back over the records and classify the males and females into groups where the data derived from each could be given statistical treatment. Only the data from the male birds are considered in this paper. The females gave the same results, though differences were less marked.

## Results of Chick Feeding Experiment

It should be borne in mind in discussing this experiment that the fish meal is merely a supplemental feed and that the fish meal protein constitutes only one-sixth to one-quarter of the total protein of the ration. The case is then totally different from the rat experiment, where the fish meal furnished practically all the protein present in the ration. The fundamental principle underlying supplemental feeding tests is admirably summed up by Mitchell and Hamilton[8]:

> "We may consider each food protein fed at a low level of intake as consisting of two fractions, one including the maximum amount of the several amino acids that can be used to replenish or enlarge the supply of nitrogenous substances in the tissues, the other including the remaining amount of the constituent amino acids destined to be deaminized, because it does not contain the complete assortment of amino acids essential for synthesis into complexes needed by the tissues. If two foods are fed together to a growing animal, those fractions of each that would otherwise be deaminized may together contain a complete assortment of amino acids, permitting a part of the combined fractions to be used for synthetic purposes. In such a case, obviously the biological value of the mixture would be greater than the weighted mean of the biological values of each."

The data obtained were treated statistically and graphically in Table 5 and Figure 2. Data on growth are calculated only on birds still alive at the termination of the trial and conforming to a normal frequency distribution with respect to weight. Table 5 shows that there was no marked difference in the weight gains made by the male chicks fed any particular sample of fish meal. For example, in Figure 2, samples 1 and 5, which showed the widest differences in the rat experiment, are practically the same. In this case the extracted meals seem to be of even slightly lower nutritive value than the non-extracted, the reverse of what occurred in the rat experiments. Sim-

TABLE 5. STATISTICAL SUMMARY OF THE BODY WEIGHT AT AGE 82 DAYS OF MALE CHICKS FED SUPPLEMENTS OF VARIOUS WASTE WHITE-FISH MEALS

| Sample No. Used As Supplement in Ration | No. Birds on Test | P* of Normal Frequency Distribution | Mean Weight in Grams | Difference in Mean Weights in Grams | Percentage Difference in Mean Weights | Dif. / P. E. Dif. |
|---|---|---|---|---|---|---|
| 1 | 47 | .911 | 1,275.5±17.0 | 168.1±26.8 | 15.18 | 6.28 |
| 2 | 46 | .695 | 1,107.4±20.7 | | | |
| 2 | 46 | .695 | 1,107.4±20.7 | —83.6±26.1 | 7.54 | 3.20 |
| 3 | 39 | .818 | 1,191.0±16.0 | | | |
| 2 | 46 | .695 | 1,107.0±20.7 | —46.3±24. | 4.16 | 1.93 |
| 4 | 54 | .163 | 1,153.7±12.1 | | | |
| 5 | 53 | .360 | 1,287.7±20.8 | 12.2±26.9 | .96 | .45 |
| 1 | 47 | .911 | 1,275.5±17.0 | | | |

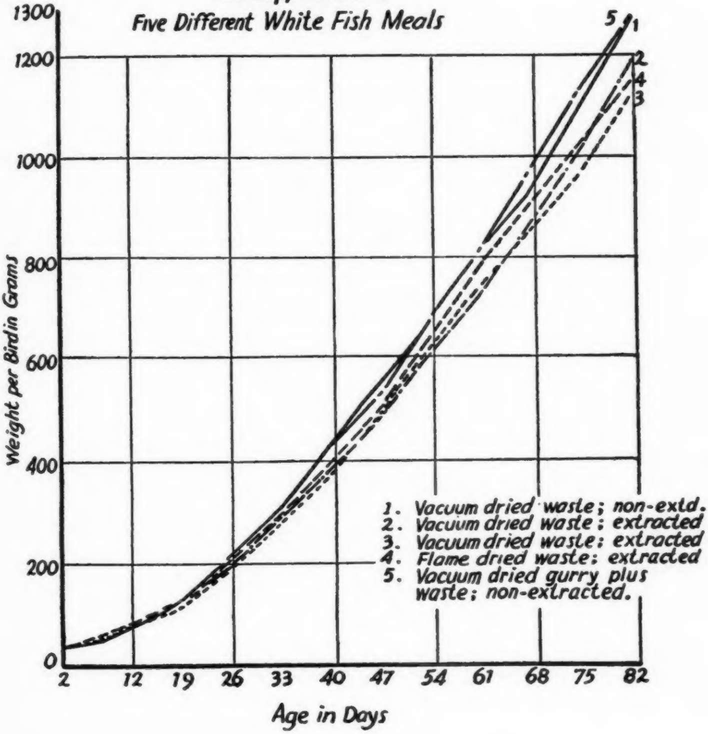
*P = probability of getting deviations as great or better than those observed in a normal frequency distribution.

ilarly there was no statistical difference between the flame and vacuum dried meals when used as supplements. With rats, the flame dried ones were inferior. In other words, the results of the chick feeding experiment do not check very closely those obtained as a result of feeding rats. The amount of fish meal protein present in the average chick or laying hen ration is relatively small and the nutritive differences between samples must be large or significant weight or egg production differences will not be found even in carefully controlled experiments.

These results emphasize the fact that the results of tests of protein efficiency can only be considered to apply to the conditions under which the tests are made. The efficiency of the protein may be entirely different when different supplementary relationships are involved, or when, even though the ration is the same, the purpose to which it is put is different. For example, supplementary relationships would presumably be different in swine feeds than in poultry feeds; and in the case of a particular poultry feed, efficiency of protein utilization might be different for egg production than for growth production, since different types of protein are to be manufactured in the two cases. Notwithstanding these facts, it is often assumed that because a protein has been reported superior as a sole source for growth in rats, it is likewise superior for any and all purposes, and in any and all supplementary relationships into which it may be brought. This research points definitely to the fallacy of this assumption in a specific case.

Additional data on the value of different whitefish meals on egg production, feather growth, pigmentation and other factors have been collected and will be correlated with the present growth data and published elsewhere.

*Figure 2.* Growth of Male Chickens Fed Supplements of Five Different White Fish Meals




## Summary

1. The chemical composition is given of whitefish meals prepared by various manufacturing methods.

2. As a sole source of protein for rats a 9 per cent casein level is adequate for steady growth. Four whitefish meals prepared from fillet and salt-fish wastes, when fed similarly to rats at levels ranging from 9 to 12 per cent, proved inadequate for sustained growth.

3. Vacuum dried fish meals were somewhat superior as sole sources of protein in rats to flame dried meals; similarly, hot water extracted fish meals were superior to non-extracted ones.

4. When these fish meals were fed as supplementary sources of protein to chicks, 2 to 82 days of age, and where the fish meal furnished from 16 to 25 per cent of the total protein, only minor differences in growth of chicks were obtained from various samples. Vacuum dried meals were not significantly better sources of protein for chicks than flame-dried. However, the non-extracted meals were slightly superior to the extracted for chick growth.
5. Results of rat feeding tests where fish meals are used as sole protein sources, should not be interpreted too broadly, or quoted to prove the superiority of a meal in poultry feeding, where the fish meal is used merely as a supplement to grain.
6. Only very carefully conducted and controlled, large-scale experiments with poultry will yield reliable results when supplementary sources of protein are compared. The balancing effect of the amino acids in the different proteins may produce results totally different from those obtained when feeding a single protein.
7. Battery-raised chicks receiving 0.756-1.19 per cent phosphorus and 1.48-2.50 per cent Ca in the rations developed slip-tendon in 0-23 per cent of the chicks.

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## Discussion

Dr. Fellers: As you know, after the commercial fisheries have taken the best part of the fish for human food the rest of it is either destroyed or made into oil or fish meal. The amount of fish meal which is available as excellent animal food or fertilizer is indeed very great, and we are looking to a better utilization of it and a fuller knowledge of its nutritive value in the feeding of animals, poultry, and perhaps even of hatchery fish. I have listened to talks on trout nutrition, and it seems to me there is an excellent opportunity to continue work of this sort in the feeding of fish meals to newly hatched fish in the hatcheries. I believe there is a splendid opportunity there for the nutrition laboratory to cooperate with the various state and government departments of fisheries and game in determining what the nutritive requirements of some of these fish, game birds or animals are.

# A CRITICISM OF THE USE OF POTASSIUM PERMANGANATE IN FISH CULTURE

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In 1930, Dr. Walter Hess inaugurated a treatment to destroy certain Trematode worms, such as Gyrodactylus and Dactylogyrus, which are parasitic on fish held under hatchery conditions. This treatment consisted in dipping the affected fish in a weak solution of potassium permanganate. This method has grave inconveniences when it is a question of treating large numbers of fish at the same time. In particular, the prolonged immersion in this still solution is apt to cause suffocation among the fish. It was to evade these difficulties that Embody and Kingsbury, in 1932, at Cornell University constructed an apparatus which permits the use of a constant volume of the reagent in a trough holding trout without interrupting the circulation of the water.

In this apparatus one puts a concentrated solution of $KMnO_4$ which, due to a floating valve, flows at a constant rate. Knowing the concentration of the $KMnO_4$, the rate at which it flows, and the quantity of water running through the trough, it is easy to treat the fish with the desired concentration.

Embody and Kingsbury did not limit the use of $KMnO_4$ solely to the destruction of parasitic worms, but also recommended its use as an efficacious preventive of other diseases. They suggested a weekly treatment for the duration of an hour, the concentrations to be used varying with the temperature of the water and the size of the fish. These concentrations are tabulated below:

POTASSIUM PERMANGANATE TREATMENT

TABLE 1. POTASSIUM PERMANGANATE CONCENTRATIONS RECOMMENDED

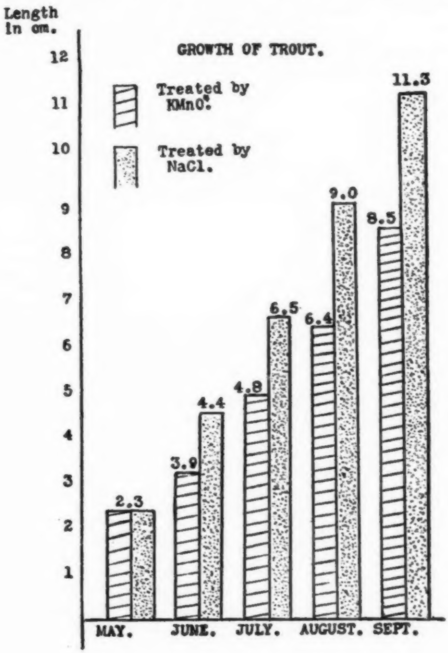
| | |
|---|---|
| For green or eyed eggs | Water temperature below 45° F.—1: 100,000 |
| | Water temperature from 46-52° F.—1: 125,000 |
| For trout 1 to 2 inches long | Water temperature below 45° F.—1: 150,000 |
| | Water temperature from 46-55° F.—1: 175,000 |
| For trout 3 inches and longer | Water temperature below 38° F.—1: 75,000 |
| | Water temperature from 38-45° F.—1: 100,000 |
| | Water temperature from 46-55° F.—1: 150,000 |
| | Water temperature from 55-65° F.—1: 175,000 |
| | Water temperature above 65° F.—1: 200,000 |

Now the use of common table salt has long been established in hatchery work, and has given good results as a preventative. We are all familiar with the manner of its use. The concentrations vary of course from place to place and time to time. The fish are permitted to remain in it until they show signs of distress and are then relieved. This treatment, however, is much more expensive than the use of $KMnO_4$, takes a good deal more time and, according to Embody, is less efficacious.

Both of these methods have been employed on a large scale for purposes of comparison in two hatcheries of this Province, one a departmental hatchery at St. Alexis des Monts and the other belonging to the St. Bernard Fish and Game Club of the same address. The concentration of the solution of $KMnO_4$ was 1:300,000, duration of treatment one half hour, the temperature between 50 and 55 degrees F. Among the trout of one place there was a loss of 14% while among the other trout the loss was 2%, and in each case fish from the same eggs were treated. What is the explanation of this difference in results?

In analyzing the factors likely to produce this inequality in the two losses, we found that the organic content of the troughs and the water was very different at the two hatcheries. And it is to this organic content that we look for the explanation of the difference in the loss experienced. It is in the water with the higher organic content that the smaller loss occurred. This hatchery, that of the St. Bernard Fish and Game Club, uses lake water as its supply. Surface and deep water is mixed to give the requisite temperatures.

At the departmental hatchery spring and creek water is used, and during the dry weather there is more spring than creek water. This



spring water has a very low organic content. The organic content, of course, uses up the potassium permanganate and reduces the strength of the solution as far as its effects on the fish are concerned. This, I think, is the explanation. The use of common salt gave a loss of 2% at each place.

An examination of the growth obtained among those trout treated with potassium permanganate and among which there was a loss of 14% shows that there was a remarkable retardation as compared with the growth of those treated with salt. This is very evident in the accompanying graph.

We must note here, however, that no loss of growth was experienced among the trout treated at the St. Bernard Fish and Game Club with potassium permanganate, where the loss was 2%, both with potassium permanganate and salt.

I have no data for each separate month, but I can say that the average length of the trout, after having been treated a month and a half, was 6.6 cm. for those treated by the $KMnO_4$, and 6.6 cm. for those treated with NaCl.

To conclude, it is my experience that the use of potassium permanganate, as suggested by Embody and Kingsbury, is good, provided that the concentrations to be used are not generalized. These should be decided independently for each location, since conditions—in this particular case, the organic content of the water—vary from hatchery to hatchery.

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# QUANTITATIVE STUDIES ON HERRING SPAWNING

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Every year many billions of herring (*Clupea pallasii*) spawn in numerous areas along the shores of British Columbia. The number of eggs deposited and the number of larvae hatched annually from all these spawnings is so great as to be almost beyond our powers of conception. The present paper, based on studies of typical spawning grounds at Departure Bay and Nanoose Bay on the east coast of Vancouver Island, provides quantitative estimates of the numbers of eggs deposited, the numbers of fish spawning, and the mortalities of eggs on the spawning grounds.

It is clear that the number of eggs deposited and the number of larvae hatched will vary considerably in different spawning areas in the same season and in the same or similar spawning areas in different seasons. A quantitative measure of initial productivity in a particular area from year to year, supplemented by studies of the abundance of larvae and post larvae in that area, and by spawning reports from all areas, might yield results with a bearing on the variation in the abundance of the year classes which would subsequently appear in the commercial catch. In other words, if satisfactory results on survival can be obtained the occurrence of dominant year classes might be predicted on the basis of the intensity of spawning. This contribution may be regarded as an exploratory investigation of the problem and as indicating the possible applicability of the methods to productivity studies in shore-spawning fishes.

## SPAWNING

In general it may be stated that the spawning of herring in the southern part of British Columbia occurs during the latter part of February, in March, or in the first part of April. The adhesive eggs are usually deposited on vegetation, chiefly eel grass (*Zostera*) or rockweed (*Fucus*) in or just below the intertidal zone. Generally all or most of each spawning bed is uncovered at low tide. The eggs remain attached to the vegetation for about two weeks, the exact length of time depending on the temperature of the water, after which they hatch and liberate the herring larvae.

At Departure Bay in 1931 spawning began at the head of the bay on March 25 and continued for about two days. A second and smaller spawning occurred on March 29.

At Nanoose Bay in 1932 there were at least three separate spawnings commencing on March 1 and lasting for about three days. Eggs were deposited in three separate areas, (1) a large area at the head of the bay, (2) a small patch on the west shore, and (3) an extensive

area at the entrance and extending in scattered patches along the shore for about one-half of a mile.

All of these spawnings took place on gently sloping shores which were uncovered at a very low tide. In all cases the eggs were deposited on eel grass which was growing in profusion in the intertidal zone. The spawnings at Departure Bay in 1931 and at Nanoose Bay in 1932 were investigated and the results form the basis of this paper.

## Methods

One or more samples of eggs from each spawning ground were obtained in the following manner: a representative patch of spawn was chosen; an area of approximately 62 square inches was marked off; all the eggs on the eel grass and those lying loose under the eel grass in this area were collected and placed in a quart jar. Some samples were preserved in 10% formalin, others in 10% acetic acid. The latter, as a fixative, enabled the dead eggs to be more readily distinguished from the living, although as a preservative it was found in some cases to be somewhat inferior to formalin.

The total area of each spawning ground was estimated by pacing and, if necessary, this value was divided by a factor correcting for irregularities in shape and distribution of the patches of eggs.

The eggs were subsequently removed from the eel grass; in a sub-sample of about one thousand eggs, those which were living and dead at the time of fixation were differentiated and counted accurately; the counted sub-sample and the rest of the total sample were both partially dried by the same method and weighed. In this way it was possible to estimate the number of eggs in each sample and, since the area of each spawning ground was known, to estimate to the nearest million the number of eggs deposited.

The method of counting and weighing was also applied to determine the number of eggs in female herring of various lengths. The percentage of female fish in the runs was obtained by making sex determinations on several hundred fish, comprising several individual samples taken from the commercial fishery in the same season as spawning took place. With these additional data it was possible to estimate the number of fish spawning in each area.

At Departure Bay small samples of eggs were also taken from different parts of the spawning beds and beach throughout the period to determine the mortality of eggs under the various conditions to which they were subjected.

## Estimates of Total Egg Production

The result of the egg counts for the various samples are included in Table 1 and the estimated number of eggs on each spawning ground in Table 2. In some cases the number of significant figures to which the results have been carried is probably greater than is warranted.

The numbers of eggs in the three samples from Departure Bay,

1931, taken on three separate days, differ considerably. This variation may be accounted for, in part at least, by the natural course of events during and subsequent to spawning. The first sample, March 25, was taken after spawning had been in progress but a short time and therefore shows a comparatively low count (30,700). The second sample, March 26, is considerably larger (108,000) and probably most adequately represents average maximum deposition. The third sample, March 31, shows a considerably lower count (64,800) and was taken after a large number of eggs had been loosened from the eel grass by wind and wave action during a storm and had been washed up on the beach into a compact mass extending for some distance parallel to the water-line. An estimate made on April 5 by another method indicated that 40% of all the eggs had been detached from the eel grass and were lying on the beach. This independent estimate is in good agreement with the above results.

TABLE 1. DATA ON EGG SAMPLES FROM 62 SQUARE INCHES OF THE SPAWNING GROUND

| Locality | Date | Number of eggs in sample | Mortality | Stage of embryo |
|---|---|---|---|---|
| Departure Bay | March 25, 1931 | 30,700 | 7.3% | Cleavage |
| | March 26, 1931 | 108,000 | 2.5% | Cleavage |
| | March 31, 1931 | 64,800 | 5.4% | Young embryo |
| Nanoose Bay, head | March 11, 1932 | 58,000 | 10.5% | Advanced embryo |
| | | 74,900 | 3.6% | Advanced embryo |
| | | 92,600 | 3.1% | Advanced embryo |
| Nanoose Bay, west shore | March 11, 1932 | 93,800 | 4.3% | Advanced embryo |
| Nanoose Bay, entrance | March 11, 1932 | 102,300 | 1.5% | Cleavage and young embryo |
| | March 12, 1932 | 80,800 | 1.4% | Young embryo |

TABLE 2. ESTIMATES OF THE TOTAL NUMBERS OF EGGS, NUMBERS OF SPAWNING FISH AND THE AVERAGE MORTALITIES ON THE SPAWNING GROUNDS

| Locality | Number of eggs in 62 sq. in. | Area of spawning grounds (sq. ft.) | Estimated number of eggs (millions) | Proportion of females in the schools | Estimated number of fish spawning (millions) | Average mortality of eggs on spawning grounds. |
|---|---|---|---|---|---|---|
| Departure Bay: 1931 | 108,000 | 300,000 | 75,250 | 41.6% | 9.03 | 5.1% |
| Nanoose Bay, head: 1932 | 75,200 | 350,000 | 61,131 | 42.0% | 7.27 | 5.7% |
| Nanoose Bay, west shore: 1932 | 93,800 | 40,000 | 8,714 | 42.0% | 1.04 | 4.3% |
| Nanoose Bay, entrance: 1932 | 91,550 | 175,000 | 37,169 | 42.0% | 4.42 | 1.5% |

The total area of the spawning ground was estimated at 300,000 square feet. Using this figure and the egg count for the sample of March 26, the total number of eggs deposited on this spawning ground is calculated to be 75,250 million.

Three samples from representative areas at the head of Nanoose Bay were obtained on March 11, 1932, some time after the cessation of spawning. Using the average of the three counts (75,200) and the estimated area of the spawning ground (350,000 square feet), the total number of eggs deposited is estimated at 61,131 million, a value simi-

lar in magnitude to that obtained for Departure Bay the previous year.

The spawing ground on the west shore of Nanoose Bay in 1932 was relatively small, comprising but 40,000 square feet. From the egg count of one sample (93,800) the total number of eggs deposited is estimated at 8,714 million.

Although spawning extended in scattered patches for about one-half of a mile beyond the entrance to Nanoose Bay in 1932, estimates were confined to the area at the entrance, the extent of which could be readily estimated. From the area of this spawning ground (175,000 square feet) and the average count of two samples (91,550) the total number of eggs deposited is estimated at 37,169 million.

## The Number of Eggs in Female Herring

Estimates of the number of eggs in ripe female herring of different lengths are given in Table 3. The numbers range from 18,200 to 29,500 and show a tendency to increase with length. It is probable that the number of eggs also increases with age and possibly this factor may account for the irregularities in the correlation between egg count and length. As the average length of female fish spawning in the vicinity of Departure and Nanoose Bays in 1931 and 1932 was from 190 to 200 mm., the average number of eggs deposited by each female fish is considered to be approximately 20,000, assuming each to be fully spent after spawning.

TABLE 3. THE NUMBER OF EGGS IN SEVEN FEMALE HERRING ACCORDING TO LENGTH

| Standard length | Number of eggs |
|---|---|
| 191 mm. | 19,000 |
| 194 mm. | 18,200 |
| 210 mm. | 22,600 |
| 214 mm. | 27,600 |
| 216 mm. | 27,700 |
| 217 mm. | 24,600 |
| 223 mm. | 29,500 |

## The Number of Spawning Herring

Knowing the total number of eggs deposited, the average number of eggs per female fish and the sex ratio, the number of spawning fish may be calculated. The results are included in Table 2. It may be seen that the number of fish of both sexes spawning in Departure Bay is estimated at 9.03 million; at the head of Nanoose Bay at 7.27 million; on the west shore of Nanoose Bay at 1.04 million; and at the entrance to Nanoose Bay at 4.42 million. As one million fish constitute approximately one hundred tons, possibly the numbers may be more readily comprehended on this basis. In 1931, 903 tons of fish are estimated to have spawned in Departure Bay and in 1932, three lots, each consisting respectively of 727, 104, and 442 tons of fish are estimated to have spawned in Nanoose Bay.

## Mortality on the Spawning Beds

Estimates of the percentage mortalities for the various samples are included in Table 1 and are averaged according to locality in Table 2. The mortalities represented by these figures include only eggs appearing as dead in the preserved samples. The percentages therefore indicate the initial mortality of eggs which are attached to or lie below the eel grass in the intertidal zone and which is caused by infertility, overcrowding, drying out, frost, or similar factors. They do not take into consideration eggs washed up on the beach or those eaten by gulls, ducks, crows, and other animals.

It may be seen that the dead eggs constituted from 1.4 to 10.5%, the latter figure being queried because of the difficulty in distinguishing dead eggs from those broken or improperly preserved in one sample. It is difficult, from the data on hand, to relate the percentage mortality to the stage of the embryo, although a relationship might be expected. It is also difficult to arrive at a reliable value for maximum mortality from the various causes mentioned above, as eggs may be continually dying and decomposing, leaving no noticeable traces of their presence. The average values in Table 2 indicate, however, that the initial mortality of herring due to "natural" causes, from the time of deposition until hatching, is about 5%. This figure is not regarded as a maximum value.

At Nanoose Bay in 1932 most of the eggs remained attached to the eel grass until the time of hatching. At Departure Bay in 1931, however, a large percentage was loosened by wind and wave action and washed up on the beach into a compact mass. Samples of these loose eggs, collected from April 1 to April 9, 1931, showed a mortality ranging from 35 to 95%, with an average of about 70%, which is a much higher value than for those attached to fixed or floating eel grass. It is probable that the true average percentage mortality is much higher than this figure, as many of the embryos which were counted as living had a distinct whitish appearance and were probably dead at the time of fixation but had not yet begun to decompose. It is also probable that each high tide would wash more live eggs from the eel grass to add to the numbers on the beach and that these eggs, while living at the time of sampling, would soon die.

It may be concluded that a large percentage, probably over 70%, of the eggs which are detached from the vegetation and washed up on the beach, fail to survive. It is difficult to estimate with certainty the number of eggs which perished at Departure Bay in this way but if, as indicated by the results, about 40% of the eggs were washed on the beach, the initial mortality on the spawning ground must have been greatly increased.

If the number of herring in the sea remains constant, if the sexes be present in equal numbers, and if an average size female fish deposits about 20,000 eggs, then only 2 in 20,000, or 0.01% of the eggs must

survive to adults. As herring spawn more than once this percentage is rather too low, but it may be regarded as a safe minimum. This means that the mortality from egg to adult must be at least 99.99%. Under ideal spawning conditions, such as that at Nanoose Bay in 1932, the initial mortality on the spawning grounds due to "natural" causes is about 5%. Possibly the ravages of birds and other animals which feed on the eggs account for not more than another 5%. Stormy weather, by detaching eggs and washing them up on the beach, undoubtedly increases initial mortality considerably. However, it is apparent that by far the greatest mortality must take place not on the spawning grounds but in the sea at some time between the larval and adult stages.

## Summary

This paper includes the results of an exploratory attempt at a quantitative study of the spawning grounds of the Pacific herring with the object of determining the number of eggs deposited, the number of fish spawning, and the mortality on the spawning grounds.

Representative samples of eggs were taken from unit areas on the spawning grounds and the number of eggs in each was estimated by counting and weighing. Knowing the total area of the spawning grounds it was then possible to estimate roughly the total number of eggs deposited. The number deposited on four spawning grounds at Departure Bay in 1931 and Nanoose Bay in 1932 ranged from eight billion at the smallest to seventy-five billion at the largest spawning ground.

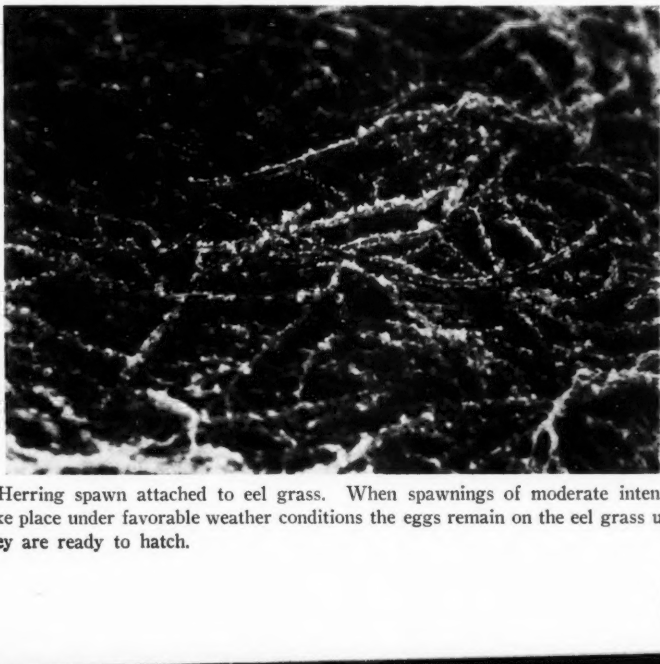
The number of eggs in an average size female fish was found to be about twenty thousand. Using this figure and the known sex ratio, the numbers of fish spawning in the four areas were estimated to range from one million at the smallest to nine million at the largest spawning ground.

The initial mortality of herring in the egg stage on the spawning ground was found to average about 5 per cent for eggs which were attached to the eel grass. This mortality was considered to result from such factors as infertility, overcrowding, and exposure.

At Departure Bay, wind and wave action caused a considerable percentage of the eggs to become detached from eel grass and pile in a heap along the beach parallel to the shore. At least 70 per cent and possibly more of these eggs died, thus increasing the initial mortality on the spawning beds considerably in this instance.

If the abundance of herring remains at a fairly constant level, the total mortality must be at least 99.99 per cent. Under ideal weather conditions initial mortality on the spawning grounds, including eggs dying from "natural" causes and those eaten by birds and other animals, probably amounts to not more than 10 per cent. It follows that by far the greatest mortality must take place after hatching, at some time between the larval and adult stages.


Departure Bay at low tide. The low lying dark area is the part of the beach covered by eel grass on which the eggs are deposited. Free eggs lying in a compact mass on the beach and a windrow of loose eggs washed up on the shore are represented by A and B, respectively.



Herring spawn attached to eel grass. When spawnings of moderate intensity take place under favorable weather conditions the eggs remain on the eel grass until they are ready to hatch.

UNIV. OF MICH.

# SOME OBSERVATIONS ON THE CULTURE OF MASKINONGE

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An outline of the game-fish qualities of the maskinonge, its distribution, spawning habits, artificial culture and conservational requirements in Ontario, has already been published (MacKay, 1931), and the March (1934) issue of "Rod and Gun" in Canada, Volume XXXV, No. 10, contained an article entitled "The Maskinonge in Ontario," by Professor W. J. K. Harkness, Department of Biology, University of Toronto.

The commercial exploitation of the species in Ontario between 1892 and 1901 before its value as a game-fish was properly understood reduced the original stock to such an extent that abundant and widespread distribution were supplanted by reduction and by restriction to widespread but more localized areas.

When its value as a game-fish was realized the Ontario Government first prohibited its capture by commercial means, then its sale was prohibited; later steps were taken to protect it during the spawning season and in 1927 artificial culture was commenced.

The importance of protecting and maintaining this magnificent game-fish in waters admirably suited to it, and in which it is now prevalent cannot be over-emphasized. Two of the ways and means of effecting these aims are as follows:

1. A thorough knowledge of its life-history and habits.

2. A thorough knowledge of the value of artificial propagation as compared with natural propagation.

In this paper we shall discuss only some observations in connection with artificial culture carried out during the past spring and summer seasons at the Belleville and Glenora fish hatcheries, located on the Bay of Quinte, the former receiving its water supply from the Bay, which is known to be a maskinonge water area, and the latter from a spring-fed lake.

After the maskinonge eggs had hardened sufficiently, they were placed in the usual hatchery jars. It was found advisable not to crowd them, otherwise the infertile eggs would not separate easily from the fertile ones. So much difficulty was experienced in effecting the separation of dead eggs from live ones that on the third or fourth day, it was necessary to transfer the eggs to floating trays made of fine bronze screening. Cotton trays were found to be dangerous, since it is difficult to see developing fungus against a white background, and a layer of fungus had a tendency to spread over the bottom of the cotton tray cutting off circulation and suffocating the eggs. The incubation period varied from six to twelve days.

When first hatched the mouth was scarcely visible. By the sixth or seventh day it was much more definite, and distinctly ventral. On the eighth day, spasmodic movements of the jaws were discernible, although the membrane between the oral cavity and the digestive tract was still intact on the eleventh day.

About the fourteenth day the mouth, which appeared to be completely formed, had migrated to a more terminal position, and was connected with the intestinal tract. By the fifteenth day the lower jaw had commenced to elongate. Shortly after this the whole head elongated and took on the typical shape of the adult maskinonge.

By the fifteenth day many of the fish were swimming up, which was in distinct contrast to the previous period when they rested for the most part on the bottom or sides of the trough, unless disturbed. It was noted that the wooden troughs were more suitable than the metal troughs. In the wooden troughs, large numbers would rest an inch or two from the bottom with their snouts up against the sides. This served the purpose of spreading the fish out more. The fry in the metal troughs were apparently unable to cling in this manner to the sides of the troughs, and hence remained for the most part on the bottom. The problem of spreading the fish out, however, is not serious, since they show no tendency to group at the head of the troughs like trout. In fact, they show very little reaction to a current of water unless it is quite strong.

## Methods of Handling Maskinonge

It was found best to turn the young fry into the troughs three to four days after hatching. No difficulty was encountered in cleaning the troughs with a feather since the young fry are quite active when disturbed and swim out of the silt and debris. Actual handling of individual fish while in the egg-sac stage should be avoided as much as possible, otherwise large losses will occur.

At Belleville the fish were retained in troughs in which a large supply of suitable food was placed. These troughs were ordinary hatchery troughs 16′8″ x 10½″ x 4″ of water. When it became evident that the fish had turned cannibalistic they were transferred to a cement fry tank outside the hatchery 18′ x 17′ x 11″ of water previously prepared as follows: In one corner a mud bottom was constructed. In this mud bullrushes, moss and grasses were planted. Algae, of course, grew in abundance. In the diagonally opposite corner both fine and coarse gravel had been placed. This left a clear area in the centre over which the current would flow from the inlet to the diagonally opposite outlet. It was found unnecessary to maintain a constant flow of water through the tank. At 3 to 4 hour intervals during the day a flow of 7 gallons per minute was allowed to go through for about 15 minutes. From about 10 P.M. to 6 A.M. no fresh water was introduced. It is

questionable, considering the few fish in the tank whether any flow at all was required.

At Glenora, as soon as the fish started to swim up, they were transferred to two small galvanized iron tanks outside the hatchery. These tanks were 6′ x 2′6″ x 7″ of water. The bottoms were covered with mud and the following plants were present: Sagittaria, Chara, Potamogeton, Myriophyllum, grasses and Spirogyra. The volume of flow of water was 1 pint per minute; the tanks being in series arrangement. The fish were fed on mosquito pupae instead of chironomid larvae.

## Feeding Habits

Examination of the stomachs of some of the fry 24 hours after the membrane between the oral cavity and the intestine had broken, showed the presence of small amounts of diatoms and algae. These were not present in any quantity, and very likely were more or less accidentally ingested.

By the nineteenth day many of the maskinonge had started to feed on small chironomid larvae and later on small ostracods. By the twenty-eighth day they refused to feed well on the above diet, and small minnow fry were introduced. They attacked these voraciously.

Some of the peculiarities of the feeding habits of maskinonge fry might well be noted here. They will pay no attention to anything that does not show movement. They will watch a midge larva or minnow and follow it up with evident intent of attacking it so long as it is moving, but if the movement ceases for a short period of time, the lunge even though it were ready to strike, will watch the minnow for a short period and if no movement ensues, it will lose all interest and swim away in search of other prey. This characteristic appears to make the feeding of anything but live food an impossibility. The feeding of ground liver, both cooked and raw, sour milk, ground fish and other dead foods was tried without success. The lunge simply refused to pay any attention to it.

Under normal conditions no body movements can be noticed when a maskinonge fry is swimming, propulsion being achieved entirely by movement of the fins. This gives the fry the appearance of floating through the water like a little dead stick and when it approaches its prey it hovers over it for some time, before striking. Then it coils into an S-shape and strikes like a snake. If the victim is another fish the maskinonge usually strikes from above and behind and hits its prey near the gill covers. Then, it wiggles the victim around until it gets the head pointed towards its throat, and swallows it gradually headfirst. Due to this habit of poising over its prey, the maskinonge often loses its victim, since the minnow fry are usually quite active and either swim away in the meantime or have started to swim away when the lunge strike, causing the latter to miss or obtain an insecure hold. Furthermore, the lateral body movements of the swimming minnow make it difficult for the maskinonge to strike accurately. This is ap-

parently one of the factors causing cannibalism among hatchery reared maskinonge fry. Since the maskinonge show no body movements when swimming and since they swim about rather slowly, under ordinary circumstances they make a very easy prey for another maskinonge poised above it. The latter can take all the time it wishes to strike and has an easy target to strike at. The fact that they will attack and eat a fish their own size makes segregation according to size a useless procedure. Cannibalism is very prevalent among maskinonge fry and is one of the main obstacles to overcome in the semi-artificial rearing of this species.

As soon as the fish swim up and start to feed it would seem desirable to place them in large ponds adequately supplied with suitable food.

## Rate of Growth

Growth is at first very slow. When first hatched, the fry measure about 0.4" and during the first three weeks there is very slow growth, approximately 0.3". During this period the fry have not eaten anything but derive their nourishment from the food-sac. The following measurements indicate the relative rate of growth prior to and immediately following the ingestion of food.

| | Hours | | | | Days | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | 5 | 2 | 3 | 4 | 5 | 8 | 12 | 19 | 21 | 35 |
| Length (in inches) | 0.4 | 0.42 | 0.42 | 0.44 | 0.44 | 0.44 | 0.49 | 0.6 | 0.65 | 0.90 |

As soon as they start to feed, growth is quite rapid. Two weeks after they start to feed, they may grow from 1¼" to 2¼". When nine weeks old, the fish had reached a length of 3½"-4".

The rate of growth of the fry and fingerlings at the Glenora hatchery was much slower than at Belleville. This may have been due to the fact that the fish were restricted to a diet of mosquito pupae much longer than those at Belleville were restricted to chironomid larvae. As soon as the fish at Belleville refused chironomid larvae, they were fed small minnows. Minnow feeding of the fry at Glenora, as indicated above, was retarded. Whether the diet was solely responsible for the slow rate of growth of the Glenora fish is questionable.

## Water Requirements

The requirements of temperature and quantity of water for maskinonge are not hard to meet. Temperatures ranging from 49°F. to 79°F. apparently had no adverse effects. A gallon of water per minute would be more than sufficient to supply the needs of 100,000 eggs or 10,000 fry in troughs such as were used at Belleville (7'8" x 10¼" x 4" of water). A number of experiments were performed to show how little water is required. Sixteen fry (egg-sac stage) were placed in 11 oz. of water in a glass graduate; they lived 5 days without

a change of water; 35 fry were placed in approximately ½ gallon of water in a spawning pan along with a little moss from a nearby pool, for aeration. They lived here for over a month without change of water and without discomfort. The experiment was discontinued when only one fish was left due to cannibalism; only two dead fish were removed from the pan during this time.

In shipping maskinonge fry practically no ice is required.

Controlling factors in maskinonge culture are:

1. A sufficient supply of suitable live food must be obtained at all times.

2. The cannibalistic tendencies of the young maskinonge must be overcome.

# THE PREDATOR AND COARSE FISH PROBLEM IN RELATION TO FISH CULTURE

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As fish culturists turn their attentions more and more to the streams and lakes in which the young sport and commercial fish, whether propagated artificially or naturally, must live and grow, they are becoming more and more concerned in regard to the relations of certain predator and coarse fish to the more desired species. As far as Canada is concerned, the report of White (1924) served to direct attention to the problem. In recent years, reports on the stomach contents of various species of fish have led to the realization that the problem is a complicated one and that the solution can only be found by recognizing the difficulties, accumulating data and carefully devising experiments.

It may be of value at this time to briefly consider certain phases of the problem with particular reference to conditions existing in British Columbia and to outline certain studies and proposed investigations.

The predator and coarse fishes may be considered under two categories, namely, those of economic value and those of no economic value. In British Columbia, the Dolly Varden char is considered an undesirable fish in salmon areas and in certain trout waters. At the same time, it has a certain status as a sport fish. Black bass are considered as serious predators on trout and salmon and every effort has been made to prevent their introduction into salmon waters. Steelhead and cutthroat trout are considered as predators on salmon.

It is evident that the problem involving char, trout and black bass is largely one in its relation to Pacific salmon. That the Pacific salmon should be given first consideration may perhaps be taken for granted in view of the fact that a large commercial industry has its basis upon the production of these species. Not only is a large annual revenue derived from these fish but a large number of men find employment in the capture, processing and marketing of the fish and there is a large capital investment. On the other hand, it is realized that trout and char also produce a large annual return and it is doubtful if a proposal to remove these species entirely from salmon waters in areas where angling attracts many persons, would be seriously entertained. At the same time, there is no question but that trout and char do take a heavy toll of young salmon and at least accurate information as to the extent of their depredations should be determined as opportunity permits.

The attitude toward the distribution of black bass in British Columbia has already been stated. This would seem to be a sound stand, firstly because black bass in their present distribution and the variety of other sport fish in the Province are sufficient at the present time to provide for the desires of fishermen and, secondly it would be unwise at the present time to allow another species to enter an already complicated and not clearly comprehended situation.

There are in the waters of British Columbia a number of fish designated as coarse fish and at the present time, at least, of no economic value. Among these are the squawfish, *Ptychocheilus oregonensis,* the chub, *Mylocheilus lateralis,* the carp, *Cyprinus carpio,* the common sucker, *Catostomus macrocheilus,* the northern sucker, *Catostomus catostomus,* the bullhead, *Ameirus nebulosus,* the yellow perch, *Perca flavescens,* the sculpin, *Cottus asper,* and the ling, *Lota maculosa.* Of these, the squawfish is definitely known to be a predator on salmon and trout (Foerster, 1925, Ricker, 1933, Clemens & Munro, 1934). The yellow perch, the sculpin and the ling are suspected of being so also but authentic data are lacking at the present time.

The first reaction in the problem of useless predators is to recommend the removal of such species. Further consideration, however, reveals that much information necessary for adequate judgment is still lacking. In the first place, no information is available as to whether trout feed upon squawfish. In the case of a body of water in which young salmon are propagated, this point will of course not enter into the argument. In the second place, if predators alone are removed, might not non-predacous coarse fish multiply enormously and greatly reduce the food supply for salmon and trout?

It would seem logical that if predaceous coarse fish are to be removed from a body of water, the non-predaceous coarse fish should be kept within limits unless it is found that the trout feed upon them and keep down their numbers. The non-predaceous coarse fish such as the chub, various small minnows, and the suckers may consume trout eggs to a limited extent, but the chief charge against them is that they consume food organisms which otherwise might go to feed trout and young salmon. On the other hand, information is again lacking as to the part these fish play in the food of trout. Furthermore, these fish may play the part of what Leopold (1933) calls "buffers," that is, they may be taken by such predators as squawfish and thereby the depredation on trout relieved.

The situation in Blue lake, British Columbia, may be an example of this where trout, squawfish and shiners occur in considerable numbers. Examination of twenty-four stomachs of squawfish showed that the majority had fed upon minnows which in some cases were definitely identified as the lake shiner, *Richardsonius balteatus.* No evidence of trout remains were found. Another illustration is probably afforded by conditions in Kootenay lake, British Columbia. Kamloops trout and kokanees (*Oncorhynchus nerka kennerleyi*) are native to the lake and occur in large numbers. Some years ago large- and small-mouth black bass were introduced. They have successfully established themselves and there is no evidence at present, although such may be obtained later, to indicate that the Kamloops trout have suffered by reason of the introduction of the bass. Apparently both feed upon the kokanee and both live their lives with little interference with one another.

The statement is sometimes made that coarse fish should not be removed because the balance of nature would be disturbed. The fact is frequently overlooked that the first step in upsetting the balance is taken when angling and commercial fishing commences. Clearing the land, using the water of tributary streams for irrigation purposes, placing extraneous materials in streams and lakes, and other human activities bring about the physico-chemical and biological changes in the waters. If the modifying factors remain constant, a new balance tends to be established. In the case of predator and coarse fish it should be possible by scientific observation and experiment to determine accurately the conditions resulting from the removal of one or more species. With adequate information, it should be possible to establish and maintain a balance at a definite and desired level by a system of scientific management. This is the problem which awaits solution and toward which definite and precise efforts should be directed.

Realizing the importance of this problem of the inter-relations among the fish of the lakes and streams of British Columbia, the Biological Board of Canada, through its Pacific Biological Station, is carrying out three lines of study and experiment.

In the first place, through the co-operation of the officers of the Department of Fisheries and many private individuals, the stomachs of coarse fish and trout are being sent from all parts of the Province for examination. Every effort is being made to obtain material from all months of the year for it is obvious that conclusions based upon summer collections alone are apt to be erroneous. It is felt that the detailed information as to the foods of the fishes is fundamental.

In the second place, the Station is co-operating in an experiment to determine the results of an attempt to reduce the coarse fish in a small lake. Blue lake, near Princeton, has for several years provided indifferent trout fishing. A private individual has undertaken to reduce the number of coarse fish by systematic gill netting. During the past two years, approximately 700 squawfish, 650 suckers and 250 other fish, chiefly Williamson's whitefish and chub, have been removed. At the same time, citizens of the vicinity have established rearing ponds for Kamloops trout and are placing yearling trout in the lake to fill the niche produced by the removal of the coarse fish. The results of the experiment will be followed as closely as possible.

In the third place, it has been found at Cultus lake, in connection with a study of the relative efficiencies of the natural and artificial propagation of sockeye salmon, that when fry are planted in the lake only five per cent at the outside survive to migrate seaward a year later. Examination of netted squawfish and Dolly Varden char has shown that these two species feed extensively upon the sockeye salmon fingerlings. At the conclusion of the present propagation study, it is proposed to make an attempt to rid the lake of these two predators and determine if there will be a resultant increase in sockeye salmon yearling migrants.

It is hoped from these studies and others which may be undertaken as circumstances may permit, eventually to obtain adequate data for the solution of the predaceous and coarse fish problem.

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## Discussion

Mr. Langlois (Ohio): This paper presents an approach to the real problem of the improvement of fishing. I have been attempting to do something of the same kind in bass rearing ponds to determine the nature of the social relationships of the fish within the pond and the control of those social relationships; and that is exactly the thing that this paper suggests should be done for natural bodies of water. Dr. Clemens is on the right track.

Mr. Harrison: We are planning to take the predatory fish out of certain waters in Florida. We think we know what should be done, but we may be mistaken. Mr. Stoddard tells me he is satisfied that the thing that has depleted the bass in Florida to a great extent is the destruction of alligators. Ninety-five per cent of the food of the alligator is turtles, and the turtle is one of the worst enemies of the black bass.

In many of our lakes the condition is out of balance on account of the millions of perch that are destroying the small black bass. We need research work on this subject. Florida has so much water and millions of predatory fish, and the bass are growing scarcer every year. We know there is some reason for it, but we do not know exactly what it is. I am delighted to know that the Bureau of Fisheries is going into the states with the view of cooperating with them and trying to work out these problems so that we shall know what is the proper thing to do.

Dr. Greeley: The problem is a very live one in New York waters. In many instances various species of fish which are not highly prized by the angler tend to crowd up to a great degree. In one lake which we studied this past summer, the primary game fish is largemouth bass, but that lake is producing about 75 per cent

of its total poundage of fish in rock bass and other species which are destructive. Rock bass consume crayfish and other food which should go to the largemouth bass, and their habits in relation to feeding on small game fish are not very well known. Our experience in the New York surveys is that the smaller species of fish are the most widespread competitors of game fish, and to some extent are probably predatory on young game fish. All through the state sunfish and rock bass are examples of that; you find them in practically every lake where people complain about the fishing. I would just like to make that point in relation to the difference between competition and predaciousness, because that is important. The larger predatory species generally receive more attention, such as the gar and others, but as far as New York is concerned I believe we have more of a problem with the smaller species comparable to the rock bass and sunfish than we do with the larger predacious fish.

Mr. Markus: Mention has been made of the various predators that compete with game fish; I wonder if anybody has a suggestion as to how to eliminate them.

Dr. Greeley: I do not claim to be able to answer that question; it is a very broad one, but my opinion is that the thing should be attacked as a local problem. For example, in a series of isolated lakes, each distinct, you find you have to study each one to ascertain what is your particular coarse fish problem rather than tackle any one species by itself and go about it as a statewide problem. You can find examples in a series of a good many hundred lakes where practically every species of fish has come to an unnatural abundance. I have seen that in suckers, rock bass, sunfish and a great many other species. The problem has to be attacked as a local one, on the merits of each case, rather than outlawing generally any one species.

Mr. Markus: The gar has been suggested in many localities as a competitor, especially to the bass. Why could not some organization undertake research and investigation to determine the value of gar fish and see if it could not be put to some commercial use? As the thing stands, we are fishing black bass because it is a desirable species, and we are leaving the gar alone because nobody wants them. I assume before man started to interfere with the balance as it was, the gar fed on the bass and the bass fed on the young gar, so that they kept a check one on the other; but since man has broken up the balance by leaving the gar to multiply in greater numbers and taking the bass, I should think some means might be discovered of putting the predators to some commercial use the same as we use our game fish.

Mr. Langlois: In connection with Dr. Greeley's statement that the individual cases should be considered separately, I want to call your attention to the fact that while you are considering the predators only by species it might easily be found that in a given pond one or two or three, or a very limited number, of large bass would be the most serious predators and more detrimental to the fish production of the pond than any number of gar could.

# THE ORIGIN AND RELATIONS OF THE RAINBOW TROUT

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The introduction of the Atlantic salmon and the European or brown trout into British Columbia has made it necessary to obtain a clearer understanding of the relations of the members of the trout genus, *Salmo*. One of the chief difficulties which has prevented a satisfactory taxonomic arrangement of the genus has been the lack of an acceptable classification of the various forms of western trout, particularly the rainbows. Hubbs has expressed the opinion that the so-called species of rainbow trout are variant forms of a single species. Kendall stated before this Society in 1921 that the main hindrance to lumping all the rainbow trout into a single species was the difference to be found in the number of scale rows and he believed this character to be constant and unchangeable. An experiment in which the number of scale rows in Kamloops trout was reduced by raising the temperature during late embryonic development has led the writer to adopt the view that the differences in the number of scale rows are determined largely by the environment. If this conclusion is accepted then all of the rainbow trout may be considered to belong to the same species as the sea-run form, the migratory rainbow or steelhead of the Pacific slope, which was described by Richardson in 1836. Similarly all of the cut-throats may be regarded as a single species, related to the coast cut-throat described by Richardson in the same year.

## The Relations of the Rainbow Trout

In spite of the attempt of Regan to classify the trout of western North America with the Pacific salmon (*Oncorhynchus*) the body of scientific opinion still places them with the Atlantic salmon and the trout of Europe in the genus, *Salmo*. The fact that the Pacific salmon are generally known as salmon and the incorrect assumption that the spring or quinnat is closely related to the Atlantic salmon have obscured the more acceptable view that the steelhead is the true salmon of the Pacific. The issue has been further confused by the tendency for rainbows to establish permanent colonies in freshwater to a greater extent than the Atlantic salmon, thus giving support to the popular use of the term trout.

It seems important, therefore, that the terms, salmon and trout, should be clearly understood. The name salmon belongs to the migratory salmonine of Great Britain and it may be taken to refer particularly to the migratory characteristics of this species. The term migratory describes the tendency for all the young to disperse downstream away from the place of hatching and may involve an extended journey in the sea, it also implies a return migration on the part of mature fish if the population is to maintain its place in a particular range of water.

The term trout was given originally to a non-migratory salmonine in Europe. It may be taken to refer to a non-migratory or less migratory habit, some of the young remaining fairly close to their birthplace. In some places trout find their way to the sea but this should not be taken as evidence for an extended migration. Fishery biologists have been prone to think of marine conditions as a hard and fast line of demarcation limiting the distribution of a species. Although this may be true for many fishes, for the salmonoids, particularly the genus *Salmo,* the sea might better be considered as a large lake or a lake as a small sea. The salt content is apparently a minor consideration in the migration of salmonine fishes.

Many writers have commented on the similarity between the steelhead and the Atlantic salmon referring particularly to their life-histories and migratory habits. A comparison of their morphological characteristics also shows that there is a great resemblance. In reality there is no clear-cut character by which all specimens of the two species may be separated. In considering the relationship of the steelhead, it seems to be closer to the Atlantic salmon, than either of the other two species, namely the European trout and the cut-throat. The cut-throat, so little known in Europe and eastern North America, resembles the European trout and it would seem preferable to regard both of them as trout-like forms, not only because they are less migratory than the salmon, but their morphological characters differ from those of the steelhead and Atlantic salmon in a parallel manner.

With regard to specific differentiation the cut-throat is the only one which is readily distinguishable; it may be recognized by its red throat-patch and by a group of small teeth on the hyoid bone. The Atlantic salmon, the rainbow and the European trout are not always so easily separated. As pointed out above, the sea-run rainbow is difficult to distinguish from the Atlantic salmon, but the freshwater rainbow, too, may be confused with the trout. The presence of the red lateral band and a combination of characters, such as the number and arrangement of the spots, the number of anal fin rays and the number of vertebrae, serve to identify the rainbow. Unfortunately many of these differences can be discerned only by persons experienced in the variations to be encountered under a wide variety of environmental conditions and sometimes a specimen must be referred to an expert for identification.

## The Origin of the Rainbow Trout

In the last interglacial period two species of trout were evolving from a single salmonine stock. This stock had probably been separated from the progenitors of the Pacific salmon (Oncorhynchid type), by the previous glaciation. The Oncorhynchid type was isolated in the Pacific, the salmonine in the Atlantic. The salmonine type gradually accomplished a complete circumpolar distribution during the interglacial period by wandering from one river system to the next. At the

same time permanent freshwater colonies of this migratory type became established and incipient species were formed. The many so-called species of *Salmo* found today in central Europe and Asia and in the southwestern United States were probably separating from the migratory type before the last glaciation began. The non-migratory habit fostered the development of distinct morphological characters, a process which can be discerned operating in the rainbow trout at the present time. The European trout and the cut-throat were evidently isolated fairly early because they are now more clearly distinguished than the Atlantic salmon and the steelhead. It is possible however, that the tendency for the latter forms to migrate to the sea has prevented a marked divergence from the ancestral type.

It seems quite probable that the stocks which produced the present forms of rainbow and cut-throat trout were cut off from the general circumpolar distribution by the last glaciation and either, they were forced southward along the Pacific drainage basin, or only the more southern populations survived. The ice barrier completely separated the Atlantic and Pacific salmonines by closing the corridor through Behring Strait to the Arctic Ocean.

After the ice melted the rainbows and cut-throats moved northward penetrating the old territory and recolonizing it as conditions became suitable. This process was aided by favorable corridors such as the valleys of the Columbia, the Fraser and the Skeena, and by the marine inundation which covered the depressed land mass following the melting of the ice. The northern part of the continent was not glaciated and the ice apparently disappeared in the north and the south long before it left central British Columbia. Likewise the ice receded from the valleys before it left higher ground. There were thus communicating channels through central British Columbia by means of which various present-day watersheds such as the Yukon, Mackenzie, Saskatchewan, Fraser and Columbia were connected. Following the melting of the ice the land mass began to rise, but before the communicating channels were cut off those species of fish, such as the char and trout, which were capable of enduring the low water temperatures caused by the mountain glaciers, penetrated the area. British Columbia is now the meeting ground of two distinct fish faunas consisting of circumpolar forms and those which were cut off in the western States during the glaciation. The pike, the ling, the lake trout, the grayling, the ciscoes, the whitefish and many of the minnows belong to the circumpolar group and are distributed across northern British Columbia and into eastern Canada. The lake trout and ling succeeded in penetrating into the zone of overlap in southern British Columbia. The squawfish, the Rocky Mountain whitefish, the Dolly Varden and the trout belong to the second group and entered from the south. The cutthroats in southeastern British Columbia apparently came in from glacial lake Bonneville and are now found at higher elevations and farther from the sea than the rainbows. As the land mass rose bring-

ing out present-day lake basins and accentuating the falls in the streams, colonies of rainbow trout were trapped by physical barriers to down-stream migration. In this way several varieties of rainbow trout may have been isolated and are now probably in the incipient stage of species formation. The sea-going habit is probably no more than an expression of a tendency to drop down into larger bodies of water in search of food. It has been shown that it is not a physiological necessity for salmon to live in salt water in order to come to maturity. In New Zealand the rich food supply of certain lakes seems to have prevented the migration of Atlantic salmon to the ocean.

## The Origin of Trout-like Characteristics

In contrast to the Atlantic salmon the rainbow has readily established itself as a permanent freshwater resident. This may be partly due to the peculiar geological history of western North America subsequent to the glaciation when the marine inundation formed a great inland sea. This sea was gradually lifted up and converted into separate freshwater basins, such as Shuswap, Okanagan and Kootenay lakes. Today there is a definite gradation in the morphological characteristics of the rainbow trout correlated with altitude and distance from the Pacific Ocean. This provides an interesting clue to the origin of the trout-like type. It would appear that the gradual but progressive loss of the sea-going habit is linked with the assumption of a different morphology. An investigation of this phenomenon may throw some light on evolutionary changes in general and clarify the problem of speciation.

In order to give a more detailed analysis, the rainbow trout of British Columbia may be divided into three types based on physiographical lines of separation, corresponding somewhat to Kendall's "zones":

1. The steelhead in the coastal region.
2. The Kamloops in the interior plateaus.
3. The mountain Kamloops in the more mountainous regions.

Correlated with the progressive increase in elevation and distance from the sea, i.e., proceeding from type 1 to type 3, the following points have been observed:

1. An increase in the average number of scale rows.
2. A decrease in the average number of gill rakers, branchiostegal rays, dorsal and anal fin rays.
3. An increase in the relative length and depth of the head.
4. An increase in the relative length of the maxillary process.
5. A decrease in the relative width of the head and body.
6. An increase in the relative height of the dorsal and anal fins.
7. An increase in the relative length of the pectoral, ventral and caudal fins.
8. In general a greater tendency toward the retention of juvenile characters,

namely, parr marks, brighter colours, larger heads and fins and a more terete body form.

An experiment in which mountain Kamloops were planted in a barren lake at a lower elevation has shown that many of these characters may change in the first generation. The notable features were the reduced scale count, reduced proportions of the head, deeper and wider body, and decreased fin proportions. The conclusion seems warranted that freshwater rainbows are capable of reverting to the original type when placed under suitable environmental conditions.

## Conclusions

Kendall believed that the trout of western North America had been evolved in and synchronously with changes in the environment. The studies of the morphological characters of British Columbia trout point to the conclusion that this process is still going on. However, it is difficult to believe that the thirty or more forms of western trout are distinctly different and that their distinctive characters are fixed.

The experimental work suggests that many of the characters are capable of reverting to the original type in a single generation. A more satisfactory explanation would seem to be that the rainbow trout is evolving under isolation into several distinct species which may be described as being in the formative or incipient stage.

Whatever the process may be which fixes the distinctive differences induced by the environment, it does not seem to have completed its work. It would appear that the interglacial periods play a significant part in producing morphological differences by fostering the distribution of a species and the isolation of certain populations. During the glacial period these differences become more or less permanently fixed. The question of how the process of fixation operates seems to be the key to the species problem in salmonoids.

# THE FUTURE OF THE UPPER MISSISSIPPI FISHERIES

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A discussion of the future of the fisheries of any part of the country must consider many vital factors which heretofore may have seemed outside the realm of practical fish culture. Fishermen are apt to charge the depletion of fishes almost wholly to pollution, heavy fishing and illegal practices. With the correction of these conditions they feel that the fisheries problems will be solved. These are important factors, of course, and of material concern, but they constitute only a part of the problem.

To my mind the principal causes of our depleted waters in the Mississippi River Valley are ill-advised drainage of extensive areas and deforestation along the headwaters of our streams. Sad to relate, practically no drainage project has proved successful as an agricultural venture. To the contrary, even though small ditched or drained plots of land may have yielded good crops for the first few years, eventually the resultant lowered water tables, not only of the drained land but of the surrounding territory, have ruined the land both for farm crops and for fisheries production.

Deforestation has left its mark on the fisheries of the upper Mississippi by contributing an added load to the streams in the form of floods and silt. The mission of the forest to hold and release moisture as needed, and its service as an obstruction against wind erosion, a contributing factor to soil erosion, has been thwarted by ruthless cutting by the lumber industry without thought of the need of replacing trees.

Deforestation and drainage have brought about silt erosion which, in some respects, is a greater menace to fisheries than pollution because more widespread and therefore more difficult to cope with. Sewage disposal plants when installed will cure the pollution evil, but it will require the interest and activity of all landowners throughout the country to overcome silt erosion. Silt erosion has not only damaged but ruined many of the streams of the Upper Mississippi Valley and fish life has become extinct because of the inability of the silt-choked waters to produce adequate fish food.

It is my firm belief that silt erosion is the ONE most serious factor with which we who are interested in the future of the fisheries have to contend. Pollution may be eliminated and controlled in a comparatively short period of time, but to control silt erosion will require the labor of thousands of people over a long period of years.

In the canalization of the Mississippi River between Minneapolis and St. Louis, twenty-seven dams will be constructed, equipped with locks to allow the passage of boats engaged in transportation. The dams may be described as steps, the pool back of one dam extending

to the base of the dam above, thus changing river conditions to those of still water or pool conditions.

Since the project is already well under construction, the question uppermost in our minds is whether or not fishing in these waters will be improved or diminished as a result of the change. Our answer is that fishing may be materially improved provided pollution is controlled, silt erosion checked, and the waters improved through control and fish cultural practices. In other words, the waters of these pools must have the aid of up-to-date aquiculture. Throughout the Mississippi Valley, many large water areas are being created for the purpose of water power projects. These waters also must be handled with the object of improving the fisheries through the practice of aquiculture if they are to be beneficial as fisheries waters and yield adequate returns.

Pollution in the upper Mississippi River Valley has been curbed to a great extent through process of law, the states requiring industries and municipalities to provide sewage disposal plants instead of dumping their wastes into open waters. The Twin Cities as well as smaller cities along the river as far south as LaCrosse, Wisconsin, have closed contracts for the construction of sewage disposal plants. Plans for the contruction of similar plants are being agitated in cities in the canalized district along the river south of LaCrosse.

To correct the evils outlined is not entirely the work of the federal government but of the several states as well. Any state that does not have in its program plans for land management, which embrace forestation and erosion control, is sadly lacking the essentials of true conservation. Fortunately, the federal government and most of the states are now working in close cooperation to overcome these obstacles.

But the fisherman wants catchable fish. A million fish planted in a stream won't satisfy him if he doesn't catch one of fishable size. The small boy must be provided with fish that he can catch with a cane pole and a pin—a fish that bites readily and habitates the water close to shore. Future fisheries appropriations depend on the kind of luck these boys have today.

Good roads and tourists have brought about heavy drains on the fisheries, but in turn have created a mammoth recreation business widely distributed throughout the entire country. This tourist and recreation business constitutes the second largest industry in the State of Wisconsin, a business of third importance in Michigan and Minnesota, and is of corresponding importance in a business way to all states in proportion to their out-of-door territory. To say this business hinges largely on the fisheries is no exaggeration, as fishing is the most popular sport of all outdoor recreations and is recognized as the greatest of all tourist lures.

What signs are more familiar to the traveller from every city, town and hamlet than "Rooms for Tourists"? What feature is advertised

in connection with the tourist business more lavishly than good fishing?

The demand for good fishing is constantly increasing and promises to be still greater as work hours are reduced throughout the nation. The twenty-seven lakes to be created by the nine-foot channel will increase the number of fishermen along the upper Mississippi many fold. To meet the ever-increasing demands the problem must be attacked on a huge scale.

Plans for basic and extensive improvements are under way by the federal, state, county and municipal governments as never before. We should expect improvements in the fisheries commensurate with the outlay of labor and funds. Supporting the agencies going forward with this work are business interests, outdoor organizations and the public at large. For who is not interested one way or another in good fishing?

In the past we have concentrated our efforts on the production of fishes for planting purposes, and more recently have undertaken stream improvement up to limits of funds and personnel. This system worked well enough before man became so active in his pursuit of wealth through utilization of our natural resources and interference with the natural order of things. Then followed deforestation, erosion and silting, drainage and pollution, plus a greater demand for improved fishing.

Along the Mississippi River great quantities of warm water fishes were supplied the river, adjacent states, and the United States generally through the reclaiming of stranded fishes from overflowed bottom land along the river. The canalization of the Mississippi will reduce this work to a small factor. The Bureau of Fisheries will establish and maintain, at favorable locations along the river, rearing ponds where warm water fishes will be reared to fingerling length for stocking throughout the Mississippi River Valley and elsewhere.

The feeder streams of the upper Mississippi are largely trout streams at their headwaters. This branch of the work will be taken care of through cooperative rearing of trout to fingerling length. The departure of planting fingerling fishes instead of fry has already been commenced and will be enlarged upon.

Surveys of lakes, pools and streams by the Bureau of Fisheries has resulted in improved aquicultural practices in this district in a limited way for several years past. This work will be enlarged upon by the Bureau and will constitute one of its principal activities, particularly in the pools formed behind the dams being constructed along the upper Mississippi River.

The improvement of open waters is a subject within itself and will not be discussed here in detail. However, in common with game management, if conditions are natural it is not difficult to increase the output of fishes, but it goes without saying that a stream with high temperatures cannot easily be changed to a trout stream. Game managers

have come to realize that without the natural cover and other necessary conditions, the mere rearing and planting of birds mean nothing. So in fish culture if a proper environment is not available or provided, little success may be expected in production.

In summing up fisheries problems in the upper Mississippi River Valley, the following recommendations are made for the benefit of the health, recreation and prosperity of all the people:

1. Reclaim and reforest drained areas.
2. Correct silt erosion through reforestation and other means.
3. Cleanse the streams by eliminating both trade wastes and domestic sewage.
4. Conserve our flood waters by the creation of large retaining pools where conditions warrant.
5. Survey and improve all open waters, including lakes, streams and impounded waters.

# OBSERVATIONS ON THE SPAWNING OF STEELHEAD TROUT

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In connection with the experimental steelhead work being done by the California Trout Investigation the following observations were made on the spawning of steelhead trout during the spring of 1933. These data were incidental to other work that was being carried on but we feel that they are of sufficient interest to be presented briefly here.

The work was done in Waddell Creek, about forty miles south of San Francisco. Although a number of steelhead and silver salmon spawn naturally in this stream and extensive observations had been made upon them, it was felt desirable to repeat the work under more fully controlled conditions. To this end, a pen was constructed of eight-inch mesh wire enclosing a portion of a pool and riffle such as is favored by the steelhead for spawning, the deeper part of the pool for shelter and the shallow end next to the riffle for the actual nest. It was necessary to select such spots in the stream as would leave the greater portion of the bed unobstructed, since the rainy and flood season is coincident with the time of spawning. Even with this precaution, the first two pens were taken out by subsequent high water and the following data were obtained at a third pen constructed on April 5 and 6. This pen was placed at a point in the stream where the flow was divided by a low bar, the major portion being diverted to the right but enough water remaining on the left to maintain a typical pool and riffle which could be protected from all but extreme floods.

Figure 1 shows the completed pen and the blind constructed for purposes of observation. The flow of the current was from right to left in this figure and the pool which afforded shelter is beneath the small alder on the extreme right. The actual spawning took place in the gravel at the lower end of the pen. The nests were started slightly above the lower fence and extended up about twelve feet to a point slightly upstream from the blind. The pen was roughly thirty-five feet in length and twenty feet wide.

We have spoken of the desire to have controlled conditions. Anyone who has attempted to observe natural spawning can appreciate the advantages of being able to bring about spawning of trout of known history within the space of a few hours and under such conditions as would make them easily observed.

The fish used in this experiment, and in one of the previous pens which was washed out by high water, were obtained from the egg taking station of the California Division of Fish and Game at Scott Creek, five miles from Waddell Creek. These fish were selected from among a lot of sea-run fish being held in a concrete tank. In both cases the females were selected by an experienced fish culturist as be-

ing too green to be stripped, but when placed in a natural environment both spawned within a few hours. The female described in the following was spawning for the first time and was sixty centimeters in length. Females of similar history and size whose eggs have been counted contained from 4,800 to 6,400 eggs.

*Pre-spawning Activities.* Two males and the large female noted above, were placed in the spawning pen at 11:30 A. M. on April 6. The female began to dig her first nest at 2:30 P. M.

She started digging at a point about two feet above the wire screen at the lower end of the pen, where the velocity of the current over the redd was moderate. The water here was approximately three inches deep. Neither of the two males assisted in the process. The larger of the males, apparently being adversely affected by the trip over from Scott Creek, showed no interest in this procedure and remained hidden during the entire afternoon under the shelter of the alder at the upper end of the pen. The smaller male took active part in attempting to stimulate the female and in following her about in her nest building.

In the actual work of digging the nest the female turned on her side and with powerful and rapid movements of the tail disturbed the bottom materials, which were then carried a short distance by the current. As this process was repeated the nest took form and finally resulted in a depression four or five inches in depth and about fifteen inches wide. After several vigorous digging operations, the female would drop back into the bottom of the nest and would seem to test with her anal fin the relative depth and width of the pit. It was evident that she was quite careful and particular in getting the nest just right to suit her needs.

That the digging of the female is able to break up and separate the bottom particles was shown to us very clearly at a natural redd just above the forks on Waddell Creek. At this point, a ford had been built for automobile passage across the stream and had been made by piling up rocks held in place by chicken wire along the downstream margin. At one side of this ford was a hard, gravel-like mixture of decomposing rock, forming a sort of hardpan bottom. We found one pair of steelhead spawning here March 27 and, remarkably enough, the female had been able to crumble this hardpan and had laid her eggs herein, as we were able to dig them up later. In fact, the female of this pair had worn away the edge of this outcrop of hardpan until it was evenly broken off near the lip of the ford. One thing that may have attracted them to this place was the seepage down through the gravel in the bottom of the ford. At low water we noted that practically all of the water ran through the chicken wire weir, none of it passing over the top. This being the case, any eggs deposited here would be assured of a good supply of water in which to hatch. White (1930), Greeley (1932), Kendall (1929), and Hazzard (1932) have pointed out that the brook trout, *S. fontinalis* in both lakes and streams tend to select places where spring water bubbles up through the gravel, assuring the eggs a rich supply of pure water and even temperature. Rainbow

trout, on the other hand, are known not to require such conditions, but they may select gravel beds at the lower ends of pools and above swift riffles, where considerable amounts of water must seep down through the gravel.

Under conditions where trout inhabit lakes lacking tributary spawning streams, we have found both rainbow and brown trout apparently resorbing eggs. While brook trout will spawn on gravelly lake shores where spring water is present, it remains to be determined whether other trout can spawn under like circumstances. Such information would be particularly pertinent to the maintenance of fish population and stocking policies for lakes lacking the usual spawning facilities.

*Activities of the Male.* The males during the nest building were often seen, both in the pen and under natural conditions, to constantly try to stimulate the female by swimming to her side and quivering slightly at the same instant. Also, particularly with nests where many small males were in attendance, a great deal of fighting and driving away of the smaller fish occurred. In several instances we saw males viciously chasing smaller males, even going to the extent of driving them out of the pool into riffles both above and below. In the accompanying Figure 2, four males will be seen ranged along the sides and lower portions of the nest. There was a total of six males accompanying this pair. Two of these from six to nine inches long, are not shown in Figure 2.

Both the attendant males and the participating male maintain a position at one side and to the rear of the female. The smaller males are kept at various distances depending upon the pugnacity of the larger male.

The male in returning to the nest from an attack on smaller fish, will often be seen to rub his nose both over and under the tail of the female in an attempt at stimulation. Perhaps the most characteristic behavior aside from defending the nest from other males, is their sliding up against the sides of the female and quivering at the same time.

*Spawning Act.* The first spawning act took place in the pen at 3:55 P. M., four hours and twenty-five minutes after the fish were placed in the pen. The act took place about six feet from the holes in our blind so we were able to observe the details with great clarity.

The female dropped back in the center of the pit with her vent and anal fin well down in the deepest part. The male instantly moved into position parallel to her. Their vents were opposite and, since he was considerably shorter, his head came only about to her pectorals. Both fish opened their mouths wide, the female particularly was seen to arch her body, raising her head so that the tip of her snout was out of water. Eggs and milt were exuded with a quivering motion by both fish at exactly the same instant. The snout of the female, where it protruded from the water, was seen to cause ripples on the surface from the quivering motion as the eggs were deposited. The white cloud of milt partially obscured the eggs from our view, but we could clearly see

the stream of bright pink eggs dropping into the bottom of the nest. They appeared to stay in a very compact group and none were observed floating from the nest. The milt settled in a more or less compact way about the eggs though some of it was carried away by the current. The whole process did not require much more than two seconds. The male during this process was on the left side of the female as she faced upstream. The female remained in a vertical position. The male inclined slightly toward her and appeared to be in definite contact.

Even though the current was moderately swift, not a single egg was seen to be swept out of the pit of the nest by the current. Since the pit of the nest was about four inches below the gravel of the sides of the nest, we were unable to see the eggs after they had fallen to the bottom. In the short interval between the time she deposited the eggs in the pit and just before she started to cover them up, we were even unable to see the eggs by standing up and looking over the top of the blind. They must have rolled into the crevices between the gravel immediately upon lodging in the bottom. Predators which might try to secure such eggs would have little opportunity to do this, due both to the fact that the eggs settled out of sight and that they were covered in a space of a few seconds by the parent female.

Regarding dispersal of the milt by the current, our observations agree with those of Peart (1920) in that it was apparently held in the pit of the nest by current eddies below the normal level of the stream bed.

These observations are in general agreement with those of Greeley (1932) with regard to rainbow trout. Although we do not believe that the natural behavior of the fish was modified to any great extent by the fact that they spawned in the pen, some differences in our observations might be accounted for in this way. First, as already noted, the time taken to complete spawning was much shorter, due to the fact that the female had been held in a trap for some time previous to being put in the pen. Secondly, although two males were present, only one participated. From other observations, we believe that only one male is essential for successful spawning, but doubtless two males could easily participate in the process. In none of the nests outside the pen have we seen eggs actually spawned though many pre-spawning and post-spawning activities were observed in such nests.

It is believed by some that fertilization under natural conditions is more or less ineffective. From our observations the milt had ample time in which to accomplish this purpose as most of it settled with the eggs and actual mixing of eggs and milt was done in a most efficient manner.

This work was originally planned to determine the number of fry resulting from the spawning of one pair of steelhead trout. As it turned out this was not possible as Cottoids (*Cottus gulosus*) undermined the screen shortly before the fry came out of the gravel. In addition the emerging fry were swept against the screen by the cur-

rent and so many of them were lost that no count could be obtained.

*Post-spawning Behavior.* Within a few seconds following the mating act, the female turned on her side and began covering the eggs. This she accomplished by digging, not directly over the point where the eggs had been dropped into the pit of the nest, but slightly to each side and forward of the nest, the current sweeping the displaced materials into the pit over the eggs. This gravel was moved into the pit within a minute. As soon as the eggs were well covered she began digging another pit about two and one-half feet above the point where she had previously deposited eggs. The male was uninterested in these proceedings and did not assist her at any time.

For protection of eggs this method offers distinct advantages. Eggs laid in the first portions of the nest are gradually buried deeper and deeper by materials being washed downstream from pits dug above as she works upstream. As was noted in both our spawning pen and in redds elsewhere in Waddell Creek, the female always starts working any given redd at its lower end near the lip of the pool. Having deposited her first lot of eggs and covered them, the next pit dug is directly upstream two to three feet above the first pit. She continues gradually working upstream into deeper water until that portion of the redd suitable to her needs is completely utilized.

One hour and forty minutes later the second pit was completed and she spawned again. This time, however, the male was on her right side obstructing our view from the blind and we did not see the eggs actually emitted, though we did see milt from the male. The procedure followed was in all respects the same as we observed at the first spawning. The act lasted about two seconds as before. She immediately covered the eggs and shortly began digging at a third pit above the point where eggs were last deposited.

Observation was discontinued at that time but was resumed on the morning of April 7. The female had left the nest and retired to the pool. She made no effort to continue spawning during the morning. In the early afternoon she was taken from the pen and killed for examination. Only seven eggs remained and examination of her coelomic cavity showed no blood to be present as is usually found in females stripped by hand. Apparently she had continued her spawning after dark and completed it during the night.

The fact that this female had been held in tanks at Scott Creek for some time and then moved into the spawning pen where natural spawning conditions were at once available, may have speeded up the spawning activities beyond a normal for fish which had not been so retarded. As other observers have noted, the spawning process of single pairs of trout, may extend from several days to a week or more. We believe this to be true of fish normally spawning in Waddell Creek.

When we examined and measured the completed redd on the morning of April 7, this area was found to be approximately twelve feet in

length and five feet wide. The depth of the water averaged about five inches over the whole area.

From the separately raised piles of gravel we believe that six or seven nest pits were dug to complete the spawning. These were in a straight line following the current. As has already been stated a female of this size would lay from 4,800 to 6,400 eggs. If six pits were utilized this would mean an average of from 800 to 1,000 eggs for each separate spawning.

An examination of some twenty natural spawning redds in Waddell Creek showed that the fish invariably selected the lower ends of pools where the water was shallow but relatively swift and where good gravel beds composed of medium and small sized stones were available. Examination of Figure 2 shows the nest of the pair pictured to be just above the point where the water breaks over the lip of the pool into a swift riffle.

We had thought previously that the digging motions and spawning motions might be one and the same act. However, it is practically impossible to see anything in the water at these times due to the disturbance of the water and bottom by the vigorous digging motions of the females. As noted above, their behavior is entirely different in each case. When spawning was actively under way in Waddell Creek in March, it was possible to hear the splashing and turmoil caused by digging females several hundred feet from the stream.

In several of the natural nests we noticed spawning pairs utilizing areas in which earlier spawning by the same species had taken place. Since silver salmon also spawn in Waddell Creek and are abundant, it would seem natural that the spawning of the steelhead in the same areas that had been formerly used by the silver salmon, would cause large losses of the latter's eggs through disturbances to their nests. However, the silver salmon have been and continue to be abundant in Waddell Creek. Just the amount of damage that results from disturbance caused by late spawning pairs we have not been able to ascertain. However, from our attempts to take eggs from both the nests of silver salmon and steelhead, none of which were very successful, we would conclude that the damage due to this cause would probably be slight.

In connection with the immature males invariably found with adult pairs, seining of these small specimens usually showed them to be ripe, and we are of the opinion that these smaller trout are there to partake of the spawning activities rather than to secure eggs to eat after deposition by the female.

In conclusion, we would like to call attention of those interested in making observations of this sort, to the ease with which wild fish can be made to spawn under natural conditions in confined areas after they have been held in tanks until nearly ripe. Fish so held will spawn in small observation pens of the type described above. With the aid of a blind, detailed observations can be obtained.

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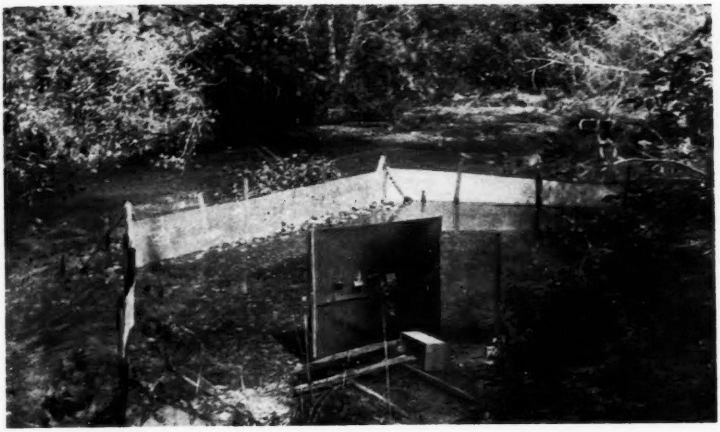

FIG. 1.—Spawning Pen on Waddell Creek, April, 1933. Blind in foreground.

FIG. 2.—Pair of Steelhead Trout over nest in Waddell Creek, April, 1933. The largest fish is the female. Note four small males ranged about sides and below nest.

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# HATCHERY TROUT AS FORAGERS AND GAME FISH

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Some anglers believe that trout hatched and reared in a fish cultural establishment are sorry substitutes for the wild fish of open waters. Some of them claim that hatchery trout planted in streams are utterly thrown away, money wasted, unless misguided persons catch them before they slowly starve and perish when deprived of their usual rations.

In order to secure some definite information as to just how hatchery trout react when suddenly placed upon their own resources, two liberation experiments were carried out recently at the Pittsford, Vermont, hatchery. An excellent trout stream adjoining the station grounds was used for the purpose.

The first experiment was begun on August 18, 1932, by liberating one hundred yearling brook trout in three equal lots, each lot marked to distinguish it from the others or from wild fish, by removing certain fins. After one lot was planted the next lot was liberated approximately 110 yards further up the stream until all the fish were planted.

It was planned to give the trout approximately twenty-four hours freedom and then to start re-capturing a daily sample of ten fish with rod and reel until all, or as many as could be caught, were recovered. All pertinent data regarding time and place of capture, extent of travel, size, sex, color and behavior as sporting fish were to be recorded. Each stomach was to be placed in a numbered bottle of formaldehyde for future examination of the contents.

The next morning, August 19, the first assault was made on the liberated trout. This consisted of two people equipped with the necessary fishing equipment, notebook, ruler, scissors and bottles for the stomachs.

A cautious approach of the brook revealed several trout still hovering over the bottom in the middle of the first liberation pool. The question now was, "Will these hatchery-fed creatures strike the fly in swift water as gallant trout should or will they sulk and demand liver?"

The answer was quickly forthcoming! No sooner had the gray hackles touched the surface than a trout struck and fought a spirited battle quite commendable indeed for a pampered degenerate! On the first page of the note book was inscribed: "Stomach No. 1—10:30 A. M., August 19, 1934—8-inch male. Colors good. Taken in mid-stream, liberation pool. Plenty of action."

Thus it went. It is not my intention to go into the details of the taking of each fish. The first day's results however, do seem sufficiently interesting for a little further discussion. In about an hour and a half

nine trout were caught. Every one of them struck in fast water and despite their lack of practice their aim was true and their courage high. Indeed, there was little about them to spell "hatchery" to a fisherman. Due to a diet designed to bring out the natural coloration, these yearling brook trout were about as pretty as any fish had a right to be. About the only real difference between these and wild trout was that the condition factor was better; that is, they were in better flesh than the usual wild trout of the same length. I do not mean fat and flabby—far from it. The meat was of excellent quality, and as no experiment is complete without a thorough investigation of all phases, let me state that when specimens Nos. 1 to 9 were shifted from the frying pan to dinner plates, I doubt very much if any complaint would have been ensuing by even the most conscientious objector to hatchery-reared trout.

The following table summarizes the stomach contents of 78 brook trout which were recovered in the course of the experiment.

**TABLE 1. TYPE AND AVERAGE NUMBER OF INSECTS TAKEN BY YEARLING BROOK TROUT LIBERATED AUGUST 18, 1932**

| Date Caught | | No. Fish Taken | No. Aquatic Insects | No. Terrestrial Insects | Average No. Both | Remarks Miscellaneous |
|---|---|---|---|---|---|---|
| Aug. | 19 | 8 | 82 | 4 | 10.8 | hatchery food in 5 |
| Aug. | 20 | 9 | 82 | 12 | 10.4 | |
| Aug. | 21 | 7 | 41 | 23 | 9.1 | |
| Aug. | 22 | 10 | 126 | 39 | 16.5 | |
| Aug. | 23 | 9 | 105 | 14 | 13.2 | |
| Aug. | 24 | 4 | 38 | 23 | 15.3 | |
| Aug. | 25 | 10 | 103 | 53 | 15.6 | |
| Aug. | 26 | 2 | 18 | 3 | 10.5 | |
| Aug. | 27 | 1 | 3 | 0 | 3.0 | |
| Aug. | 29 | 8 | 45 | 7 | 6.5 | |
| Aug. | 30 | 7 | 83 | 23 | 15.1 | |
| Sept. | 5 | 3 | 18 | 4 | 7.3 | |
| Totals | | 78 | 744 | 205 | 12.2 | |

| | | |
|---|---|---|
| Aquatic insects ............79% | Aquatic Insects: (Chiefly midge larvae and simulium) | Mayfly nymphs ............49% |
| *Terrestrial ............21% | | Caddis worms............34% |
| | | Miscellaneous ............17% |

*Terrestrial: No separate percentages figured. Beetles and flies chiefly. A sprinkling of a wide variety of forms.

Were these fish actually competing for their food against the trout already established in the stream? Specimen number 9 answered the question in a rather spectacular manner. At the rise, the fisherman hooked and landed not only the fish in question, but also a wild rainbow of approximately the same size. This looked like real competition for rainbows have a way of getting there all at once when they sight something desirable. Even so, the brook trout was more firmly hooked. An examination of the stomach showed that it was full. Although the posterior end contained the remains of the last hatchery meal, the anterior was crammed with 13 freshly caught caddis worms, and one

mayfly nymph. In fact, the data secured on the day following the liberation of the trout, showed conclusively that they were capable of foraging for themselves at once. Even though the last hatchery food given them had not yet been completely digested they were ready and willing to take advantage of anything their new environment had to offer in the way of sustenance.

### Alert from Start

These data appear worthy of a little further discussion. First, if it is assumed that hatchery-reared fish are woefully ignorant of the proper procedure necessary to keep their heretofore well-filled stomachs functioning in a satisfactory manner, it might also be assumed that each day's freedom would increase their ability to master a new environment by means of a better acquaintance with the available food supply. Thus we might expect to find food organisms progressively more abundant in the stomachs from day to day. Such however is not the case. The average number of insects in each fish holds fairly constant for the first three days, followed by an increase on the fourth day following freedom, which also marks the maximum average for any day's sample. There is nothing resembling a daily increase in the number of forms taken. It must be concluded therefore that the trout were on the alert from the very first, and that the varying amounts of natural food found in the stomachs depended on a great variety of factors, rather than on the one supposition that hatchery-reared fish are handicapped by a wrong start in life that will forever limit their ability to be successful foragers.

Before taking up some further aspects of the liberation experiment it might be well at this time to see how rainbow trout reacted under what amounted to identical conditions. The same number of rainbow yearlings, that is, 100 fish, were set free the following summer and in the very same pools in which the brook trout were placed. The procedure of recapturing and recording the data was identical.

On September 3, 1933, the day following liberation, the first attempt was made to recover some of the rainbows. Many of them could be seen in the clear water of various pools, but they showed a typical rainbow moodishness about rising and only two fish were taken the first day. The next morning however, found the fish rising with zest and this was the only time during the entire experiment in which the desired quota of ten fish could be taken. The fish could often be seen feeding on caddis worms, taken off the bottom stones, but at such times nothing the fishermen had to offer appeared to interest them in the least.

TABLE 2. SHOWING TYPE AND AVERAGE NUMBER OF INSECTS TAKEN BY 49 YEARLING RAINBOW TROUT LIBERATED SEPTEMBER 3, 1933

| Date Caught | No. Fish Taken | No. Aquatic Insects Eaten | No. Terrestrial Insects Eaten | Average No. Both | Other Food and Remarks |
|---|---|---|---|---|---|
| Sept. 4 | 2 | 2 | 0 | 1.0 | Moss in 1 fish. |
| Sept. 5 | 10 | 31 | 0 | 3.0 | Algae in 3 fish. |
| Sept. 6 | 1 | 6 | 1 | 7.0 | —— |
| Sept. 7 | 1 | .. | .. | —— | Empty. |
| Sept. 8 | 3 | 9 | 1 | 3.3 | 4-inch trout in 1 fish. |
| Sept. 9 | 6 | 26 | 0 | 4.3 | Algae in 4; algae moss, hemlock needles in 1, feather in 1. |
| Sept. 10 | 8 | 45 | 2 | 5.9 | Algae in 4. |
| Sept. 11 | 1 | 5 | 0 | 5.0 | Algae in this fish. |
| Sept. 13 | 1 | 12 | 1 | 13.0 | Algae in this fish. |
| Sept. 14 | 3 | 349 | 7 | 118.6 | 1 fish crammed with transforming mayfly nymphs. |
| Sept. 15 | 1 | 0 | 1 | 1.0 | —— |
| Sept. 17 | 3 | 10 | 3 | 4.3 | Algae, moss, seeds, sticks, half of bulk in 1 stomach |
| Sept. 20 | 4 | 18 | 7 | 6.3 | Algae, hemlock needles in 1, and 1 fish with 2 blackberries. |
| Sept. 24 | 3 | 23 | 3 | 8.7 | Algae, moss, 60 hemlock needles in 1; algae in 1. |
| Sept. 25 | 2 | 7 | 4 | 5.5 | 1 fish full of chicken feathers; 1 with algae. |
| Totals | 49 | 543 | 30 | 12.1 | Trace of moss or algae in about ½ the fish, but prominent in the 19 fish listed here. |

| | | | | |
|---|---|---|---|---|
| Aquatic Insects | 95% | Aquatic Insects: | Mayfly nymphs | 65% |
| *Terrestrial | 5% | | Caddis worms | 16% |
| | | | Stonefly nymphs | 11% |
| | | | Diptera | 4% |
| | | | Miscellaneous | 4% |

*Terrestrial: No separate percentages figured. Beetles, flies chiefly. (Note: spiders and millipedes lumped with terrestrial food.)

The above table summarizes the stomach contents of 49 rainbows which were recaptured. As in the case of the brook trout, there is nothing to suggest that as the days past the fish were learning more about foraging with consequently better-filled stomachs in the daily samples. The maximum average of food organisms is found in three fish taken on the eleventh day following liberation, but this has little significance in itself. The average number of insects per fish for the duration of the experiment is practically identical with the results obtained with the brook trout. The rainbow stomachs also showed that this species of trout takes algae and moss in a much greater degree than brook trout, a fact which has often been mentioned by other investigators. Other than this, the same type of food was found in both species, and both species seemed quite capable of looking out for themselves at once.

## Hatchery Trout Sportive

To those who believe that hatchery fish are trusting creatures; that when placed in a stream they will blithely scull up to the designing

angler and beg him for small favors, let me say that the liberation experiments with the brook and rainbow yearlings showed these notions to be more than slightly exaggerated.

As already mentioned, it was the intention to take ten fish per day until all had been recaptured, but this proved difficult to carry out. The brook in both years was low and clear and as much care had to be taken to keep hidden from the hatchery-reared fish while casting as in any normal fishing. It must also be mentioned that there were no other anglers on the stream to disturb the fish, for the experiments, to be successful, had to be carried on after the regular Vermont season had closed. Competition was thus eliminated. Furthermore, both anglers engaged in capturing the fish were very familiar with the section of the brook in question, having fished it time and time again. They knew just how to present flies in any one pool to make them appear most inviting. And finally, the exact number of prospective victims was known, just where they had been placed, and just where they would most likely go. Thus it appeared as if the anglers had everything their own way, but the supposedly unsuspicious, hand-reared creatures had ideas of their own.

It is no exaggeration to say that the fish recaptured were well earned. The rainbows particularly "came hard." It was rather annoying to observe a dozen in a certain pool calmly ignore the offered lures despite the best efforts of the anglers. Not a fish in this pool was taken until the seventh day following liberation, and then only by means of a lowly worm when the water was murky from a heavy rain. When pricked, both rainbow and brook did their best to escape by leaping from the water or boring against the bottom in a manner gallant enough to bring a smile to the face of any angler. Of the two species, the rainbow, as already mentioned, was harder to catch. Fishing for rainbows continued with varying intensity up to and including September 25, 1933, with a final tally of 49 fish recaptured. During this period despite offerings of everything from trout flies to grasshopper and worms, the fish responded only when it pleased them to do so.

Fishing for brook trout continued from August 19 to September 5 with the good recovery record of 82 per cent of the 100 trout liberated. Figuring up the time spent in capturing the brook trout, I found that it required approximately fifteen minutes of fishing effort by two people for every trout captured. This does not indicate that the hatchery trout were easy to apprehend.

As for the appearance of the trout, both species were very easy to look at. They were not the typical, dull-colored, pot bellied type of trout which used to be found all too often at hatcheries. They were nice heavy-shouldered fish, lithe and trim. A diet containing a liberal percentage of salmon-egg meal had resulted in colors that no wild fish would have been ashamed of. Spots on the brook trout were red, the bands gleaming on each side of the rainbows were red, fins of both species were brightly tinted. As for size, although not to be compared

with the large trout which can be taken from relatively unexploited waters, they would make a very satisfactory reward for angling in civilized territory.

## Movement of the Fish

The rainbow trout reacted differently than the brook trout of the earlier experiment. That is, the tendency to run with the current was much greater. For example, out of 49 recaptured rainbows, 58 per cent were taken downstream from the liberation pools, 29 per cent in the pools themselves, and only 13 per cent upstream from them. On the other hand, 82 recaptured brook trout reacted in opposite fashion, 61 per cent being caught upstream from the places of planting, 23 per cent from the pools themselves and only 16 per cent downstream from them.

It took several days for the brook trout to work upstream so that fish from one liberation pool would overlap those from a pool further up, but rainbows were taken the second day following their freedom as far as 300 yards below the place of planting. The rainbows without doubt showed their tendency to drift, fish being observed after 10 minutes' freedom 30 yards further downstream. This trait of rainbow trout, disliking to "stay put," is one of the major objections to indescriminate stocking with the species.

When it was discovered that the rainbows were going to be difficult to recapture, several efforts were made to find the fish for as much as half a mile below the lowest liberation pool, but not until the fishermen had worked up within a hundred yards or so of this spot was a single marked trout taken. At the same time, many wild rainbow were caught so there was plenty of evidence that the fish were feeding.

The observation was interpreted as meaning one of two things—either a great many fish had kept moving until they were out of reach far down the brook, or else they had found protected spots within a hundred yards or so of the liberation pools and were merely refusing the lures as was so often the case. A later checkup about the middle of October showed that numerous fish were still remaining in the same section of the brook in which the others had been taken. When legal fishing opened again last May fishermen were asked to be on the lookout for the marked fish. On the first morning around 10 fish were taken. These had passed the winter and the spring, with its freshets, in the immediate vicinity of the place in which they had been liberated.

It would seem that the particular strain of rainbows used, revealed a tendency to "stay put" a little more pronounced than ordinary. Observations on marked fish in a different brook agree with this contention.

In conclusion, it does not seem that hatchery life will have much evil effect on the gallant nature of trout . . . provided they are given proper food, care, and a reasonable natural environment. The liberation experiments proved that rainbow and brook trout, reared by

thoughtful methods, can take admirable care of themselves when placed on their own resources. Both species, despite enforced civilization, lived up to the sporting standards of their race in every respect. It is hardly a matter of argument to contend that fishing in civilized sections is utterly dependent upon the hatcheries—and therefore it is up to the hatcheries to see to it that the trout produced are worthy of the name. When trout that look like real trout are put out in trout waters for trout fishermen to catch, I firmly believe they will act like trout, which sums up the whole matter in few words.

## Discussion

Mr. Catt: I would just like to say, in support of the contention that hatchery trout have to forage for themselves, that from the time the fry are free swimming to the time they reach the fingerling stage or become larger fish there is always some small natural food supply in the water, and if you observe closely you can see the smallest fish take midges from the surface of the water. They feed largely upon the daphnia and copepods that are in the waters at the time, and there is no reason to believe they would not get these natural foods in the natural waters.

# A NOTE ON THE USE OF PHYSIOLOGICAL SALINE AS DEFINED HEREIN AS AN AID IN THE ARTIFICIAL SPAWNING OF SPECKLED TROUT

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A large amount of work has been done on the physiology of the sperm and ovum of fish and the use of physiological or normal saline as a means of prolonging the vitality of the sperm has been known for some time. For instance, in 1892 Reighard observed that the spermatazoa of wall-eyed pike and whitefish, which normally die in less than a minute in water, live for much longer periods in a 0.75 per cent salt solution. He stated that "In salt solution of 0.75 per cent the spermatazoa of the whitefish may live for twenty-two minutes or longer, while those of the wall-eyed pike remain active for about a half hour and individual spermatozoa may sometimes be seen moving at the end of an hour."

This paper is not submitted as an original contribution but rather with the idea of adding more data to our present knowledge. The experiments were carried out while the author was temporarily stationed at the Provincial Trout Rearing Station at Dorion, Ontario. Since they were not started until near the end of the spawning season, they were not as extensive or as complete as they might otherwise have been.

The composition of the physiological saline as used in the experiments included in this paper was as follows:

| | | |
|---|---|---|
| Sodium chloride | 0.7 | gm. |
| Potassium chloride | 0.025 | gm. |
| Calcium chloride (dry) | 0.03 | gm. |
| Distilled water | 100 | c.c. |

Experiments to check the effect of normal saline on the spermatazoa of speckled trout showed that, while they normally die in less than sixty-five seconds in water, they are quite active for four minutes in normal saline and slight movement could be noted for as long as eight minutes.

The so-called "dry method" of spawning was used throughout the experiments and all the spawning operations were carried out by the hatchery staff. In using the normal saline, the latter is simply substituted for the small amount of water present in the spawning pan when the dry method is used. An effort was made to keep the quantities of water, in the one case, and normal saline, in the other, equal.

## Experiment 1

On November 28, 1932, eggs from two speckled trout were spawned into physiological saline and milt added. They were left for three

minutes, during which time they were stirred with a feather. They were then washed, hardened and placed on a tray in the regular manner.

A similar quantity of eggs that had already been spawned that day in the routine manner, using water in the spawning pan, was set aside in a separate tray, in the same trough as those spawned in the normal saline. These eggs were watched carefully until all had hatched, an accurate count being kept of the infertile eggs, which were picked out from time to time. Shortly before hatching time, the eggs in the individual trays were accurately counted. This process was carried out in all the subsequent experiments given below, with variations as noted.

As shown in Table 1, the salt solution proved to be advantageous, 88.1 per cent of those spawned in the normal saline hatching as against 73.1 per cent of those spawned in water.

TABLE 1

| | Spawned in normal saline | Spawned in water |
|---|---|---|
| Original number of eggs in experiment | 1,335 | 1,346 |
| Loss before hatching | 159 | 362 |
| Percentage loss | 11.9% | 26.9% |
| Percentage hatched | 88.1% | 73.1% |

Temperatures at time of spawning—Air, 46° F.; Water, 42° F.

## Experiment 2

On November 30, 1932, eggs from a single female were divided as equally as possible between two spawning dishes, one containing a small amount of water and the other an equal quantity of physiological saline. They were allowed to stand four minutes before milt was added from a single male. The milt was left on the eggs for two minutes in each case and then the eggs were washed and treated as in experiment 1. The object was to determine the effect of the salt solution on the permeability of the egg membrane.

As shown in Table 2, 49.4 per cent of the eggs hatched from the normal saline group whereas only 32.4 per cent of the others hatched. Thus the eggs are affected less when allowed to stand in normal saline than in water. When compared with the results obtained in experiments 1 and 3, it also demonstrates the fact that the eggs should be fertilized as quickly as possible after being stripped from the female.

TABLE 2

| | Spawned in normal saline | Spawned in water |
|---|---|---|
| Original number of eggs in experiment | 77 | 108 |
| Loss before hatching | 39 | 73 |
| Percentage loss | 50.6% | 67.6% |
| Percentage hatched | 49.4% | 32.4% |

Temperatures at time of spawning—Air, 34° F.; Water, 42° F.

## Experiment 3

The remaining eggs obtained on November 30, 1932, were used in

this experiment. The eggs from each female were spawned into two dishes, one containing normal saline and the other an equal quantity of water. An effort was made to divide the eggs equally but was not entirely successful. As each female was spawned, milt from a single male was put into each of the two dishes, i.e. divided between the two dishes. After allowing three minutes for fertilization, the eggs were washed and treated in the usual manner. In this experiment, 75.8 per cent of those spawned in normal saline hatched whereas only 59.4 per cent of those spawned in water hatched. Details of the results are given in Table 3.

TABLE 3

| | Spawned in normal saline | Spawned in water |
|---|---|---|
| Original number of eggs in experiment | 961 | 1,508 |
| Loss before hatching | 233 | 613 |
| Percentage loss | 24.2% | 40.6 |
| Percentage hatched | 75.8% | 59.4% |

Temperatures at time of spawning—Air, 34° F.; Water, 42° F.

## Experiment 4

On December 5, 1932, the last stragglers of the season were spawned. The milt from each of two males was divided equally into two spawning pans, one containing normal saline and the other an equal quantity of water. The milt was allowed to stand for two minutes before eggs from a single female were added, an effort being made to divide the eggs equally between the two pans. After allowing two minutes for fertilization, the eggs were washed and treated in the usual manner. The results of this experiment were most decisive, 78.2 per cent of the eggs spawned in the saline hatching while only 5.8 per cent of those spawned in water hatched (see Table 4). This experiment indicates the advantage of using normal saline in the process of artificially spawning speckled trout.

TABLE 4

| | Spawned in normal saline | Spawned in water |
|---|---|---|
| Original number of eggs in experiment | 229 | 347 |
| Loss before hatching | 50 | 327 |
| Percentage loss | 21.8% | 94.2% |
| Percentage hatched | 78.2% | 5.8% |

Temperatures at time of spawning—Air, 29° F.; Water, 41° F.

## Summary and Conclusions

The short life of the spermatazoa, after being emitted from the male fish, is a limiting factor in the fertilization of speckled trout eggs. Anything that can be done to lengthen this period of the life of the sperm will automatically increase the percentage of fertile eggs obtained.

The experiments described in this paper show that the use of physiological saline in place of water, during the actual process of artificially spawning the trout is distinctly beneficial and lowers the loss due to infertile eggs.

The salts necessary for making up a certain quantity of normal saline can be conveniently obtained combined in the form of tablets and hence the solution can be easily made up whenever and wherever required, thereby making it very suitable for practical use.

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## Discussion

Dr. Belding: May I inquire what was the composition of your physiological saline?

Dr. MacKay: Sodium chloride, .07 grams; potassium chloride, .025 grams; calcium chloride, dry, .03 grams; distilled water, 100 c.c.

Dr. Belding: This is a very interesting and illuminating paper, which I imagine will be taken up by various fish culturists. The reason I asked the question is this: I wonder whether you can term that solution a normal or physiological saline, because normal or physiological saline is usually considered to consist of a sodium chloride only. I think the title "Normal Saline" or "Physiological Saline" for that solution is a misnomer and might be misleading.

Mr. Dinsmore: If I followed the paper closely, the highest fertility, even with the saline solution, was in the low 70's; is that right?

Dr. MacKay: That is right.

Mr. Dinsmore: I can hardly understand the necessity of using a saline solution when so much higher fertility than that is ordinarily secured by the dry method, and by the dry method I understand the use of no water at all. In a collection of approximately ten million brook trout eggs last season, our lowest fertility was about the same as that secured by the saline solution, while our highest fertility—and that applied to a large percentage of the eggs—was in the 90's. Mr. Atkins a good many years ago showed that the spermatazoa retained its activity very much longer if mixed only with the slime that came from the fish. It seems rather surprising to know that it does retain its activity for a relatively long time. Thirty years ago, while working with Mr. Titcomb on one occasion, we ran out of male fish at one spawning station, and I sent an attendant to another one two miles away, where he obtained some milt, placed it carefully in a bottle, sealed it with paper and paste and brought it back that distance of two miles. With that milt we fertilized 50 per cent of a lot of brook trout eggs.

Dr. MacKay: The highest figure given here is, in the first experiment, 88.1 per cent, as against 73 and, in the other case, 78.2.

I just wish to point out to Dr. Belding that before leaving Toronto, I asked an authority on the subject whether he would consider .75 a physiological or normal saline solution, and he answered in the affirmative.

Dr. Belding: That was not the point I made. It was that ordinarily among physicians and laboratory workers where we speak of normal saline or physiological saline we mean a solution of sodium chloride.

Mr. MacKay: Of course it is explained in the context of the paper.

Mr. White (New Brunswick): A considerable amount of syrup comes from the body of the female when the eggs are taken. Reference was made to that being the water from the female; does that not contain some salt, and are you not increasing the salinity of the medium with which they are fertilized? Do you know, Dr. Belding, the chemical composition of the syrup from the female?

Dr. Belding: No, I do not, but it would be equivalent to blood serum.

Dr. Greeley: In connection with what Mr. Dinsmore has said, I might mention that a number of years ago Dr. S. H. Gage, of Cornell, who happened to be working with a dark field microscope, asked me if I would like to look at the sperm of any fish. I brought in a ripe sucker and a ripe horned dace, and we were able to observe the evacuation of the sperm in these species. The sperm was very inactive in the fluid of the testes, whereas as soon as water touched them they began an activation which ended in their death. Although I have never observed the activation of trout spermatazoa, I think it is very likely the same thing; they do not expend any energy as long as they are in the fluid in the testes, and when the water strikes them they begin an activation which is very short and then they die very quickly.

Dr. Belding: My experience is exactly the same as that of Dr. Greeley, namely that with the brook trout there is frenzied activity on the part of the spermatazoa the moment they reach fresh water, which rapidly diminishes and ceases within forty-five seconds.

# FACTORS INFLUENCING RETURN OF SALMON FROM THE SEA

A. G. Huntsman

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The view seems to be rather generally held that the time when salmon return to fresh-water from the sea depends upon their nature and that the stream to which they return depends upon their previous association with it. While these form parts of the truth, they should not so engross our attention as to obscure other parts. A study of the return of the Atlantic salmon on Canada's eastern coast shows the operation of quite a number of factors, and the picture presented for a particular place and a particular time is seemingly dependent upon a particular combination of these factors, which may determine where and when the salmon return to fresh water. Owing to these peculiarities it seems necessary to consider only this species and for the rivers or districts with which I am most familiar.

## Temperature of the Sea

In the spring salmon begin to appear near or at the surface of the sea, and hence approach the shore, where they are taken in such fixed shore fishing gear as weirs, traps and gill nets. Perhaps the earliest appearance is around the first of May, when they begin to be taken by weirs in the narrow part of Minas channel (near cape Split) at the head of the bay of Fundy. Here the comparatively shallow inland water, warming rapidly under a progressively higher sun, is very thoroughly mixed with the deeper water in which the salmon presumably winter, and thus brings spring conditions to the latter at a relatively early date. Going farther seaward into the bay of Fundy the appearance of the salmon is later and later up to as much as a month or more. While this appearance near the surface does not seem necessarily to involve a return to fresh water, it is an essential precursor for such return, which is made distinctly seasonal by the annual temperature cycle in the sea.

There is very considerable variation (one to four years or more) in the time spent by salmon in the sea before first returning to fresh water. Temperature would seem to be one of the factors concerned in this variation. In the two branches of the bay of Fundy at its head the thoroughly mixed water warms up to the neighborhood of 15° C. during the summer, while in the outer part of the bay very little of the water goes above 10°. The salmon at the head of the bay return almost wholly as grilse or "fiddlers," that is, during their second season in the sea, while such form but a small proportion of the salmon of the rivers of the outer part of

the bay. It is to be expected that those living at higher temperatures in the sea will mature earlier.

## River Control of Salmon in Sea

There is definite evidence that the water issuing from a river into the sea is of great importance in determining the entrance of salmon into that river. How the effect is exerted is not very clear. Whether it be through temperature, oxygen content, or some peculiar characteristic of the river water, the important thing is that the salmon seem to be guided by it to the river mouth, and that rivers exhibit great differences in degree of perfection in such guidance. Although the salmon, if given time, is fairly certain to find some stream into which to run, the return to fresh water may be delayed very considerably.

The Saint John river of southern New Brunswick exercises a very perfect control over its salmon. All the returns of the many salmon tagged (after spawning) by the Department of Fisheries and liberated near the mouth of the river have been from the river system or from that part of the bay of Fundy over which the water from that river flows. There has been no evidence of straying to another river system (Huntsman 1931, p. 90). Also the great bulk of the virgin fish entering the river are very uniform in size, which means in sea age (length of time spent in the sea). Those of a certain sea year-class practically all return to the river within the space of a year. A small proportion enter during the summer as grilse, another, perhaps slightly larger, lot as late autumn fish to remain in the river almost a year before spawning, and the main lot as the ordinary salmon of 10 to 15 lb. weight from May to early August (principally in June) of the next year. It is rarely that a fish that has remained longer in the sea is ever taken in this river system.

The conditions seemingly responsible for such a comparatively limited variation in the character of the returning fish are a large volume of river water from an extensive area throughout New Brunswick and northern Maine, and its storage in a very extensive reservoir inside the reversing falls at the river mouth, so that there is a comparatively large and regular discharge into the sea. As shown by the experience of the fishermen that operate drift nets for these fish, the salmon on coming to the surface congregate, not near the shore, but along what seems to be the issuing stream of water of camparatively low salinity from the reversing falls, which stream extends from the river mouth well towards the mouth of the bay at the island of Grand Manan.

The Margaree river of western Cape Breton island presents a marked contrast to the conditions just described. The tagged fish that were liberated in this river near its mouth have been re-

captured, not only in the river and its immediate vicinity, but at various points along the neighbouring coast, which has quite a number of salmon rivers, from 85 miles to the southwest near Pictou to 115 miles northeastward and around the northern part of the island, in St. Ann's bay. Further, quite a considerable number of the recaptures have been from the coasts of Newfoundland and Labrador. On the other hand, the Margaree salmon of a given year-class in their return to the river as virgin fish are well distributed over a period of somewhat more than two years, ranging in size from grilse of three to five pounds to large salmon of over twenty pounds weight.

Corresponding with this behaviour of the salmon, the Margaree river has a very fitful discharge of water in any considerable volume. Unless in freshet condition, the river water can be traced in the sea from the harbour mouth only with ebb tide and for a comparatively short distance. For this river, volume of discharge is a very potent factor in determining the times and numbers of the entering salmon, and it would appear that quite a considerable portion of the stock, particularly of the older and larger fish are altogether lost to the river through passing beyond its influence.

## Wind

It is a very general experience among salmon fishermen that a breeze blowing from the area, over which the fish may be supposed to be distributed, to the location of their gear (for example from the sea to the shore) increases their catches unless there should be interference with the actual operation of the gear. Presumably the salmon are carried in the movement of the surface water effected by the wind. Salmon fishermen of the Margaree river report that to have fish enter the river in any numbers there is necessary, not only high water in the river, but a wind blowing from sea toward the mouth of the estuary (from the north or northwest).

## Water Movements

At the time of their return to fresh water salmon are to be found near the surface of the sea, and will be affected by the movements of the superficial water, such as those caused by the wind. There is a rather striking similarity between the distribution of the salmon taken on the shores of the bay of Fundy and the distribution of drift bottles set adrift outside the mouth of the bay in 1926, picked up on those shores. In each case the northwest or New Brunswick shore, particularly the inner half, shows few or none, and the southeast, or Nova Scotia shore, has them in two lots separated by Digby gut, the outer lot centered at Gulliver cove and the inner lot centered near Hall Harbour. Whatever may be the determining forces, it seems clear that the salmon are, like the drift bottles, carried to the shore in the movements of the superficial water.

The two lots of salmon that have been mentioned as being taken on the Nova Scotian shore are not directly related to any rivers, as the land rises very steeply and possesses only diminutive brooks. The fish of the two lots appear to originate respectively, the outer from the Annapolis river system and the inner from the Minas river system. The very thorough mixing of the waters of these systems with the very salt water of the bay in Digby gut and the narrow part of Minas channel respectively would seem to prevent practically all the salmon that move out into the bay from finding their way back. These mixing places appear as distinct and considerable gaps in the distribution of the salmon as between bay on the one hand, and basin (Annapolis or Minas) and river estuaries on the other. Such gaps do not exist between basins and river estuaries, nor is one to be found at any point in the Saint John system from far out in the bay to the uppermost waters frequented by salmon.

For the Minas system fluctuations in the outside catch are to quite an extent the reverse of those in the inside catch, indicating alternative distribution of a common stock (Huntsman 1931, p. 23). There is some local belief that the outside fishery is better after a hard winter, and conversely that the inside fishery is better after a mild winter. During a hard winter there is much snow, which remains until spring and gives a heavy freshet. During the period from 1917 to 1931 inclusive the heaviest discharge for the months of March, April and May combined, in Paradise brook (the best available for that period) as measured by the Hydrometric Bureau of the Dominion Water Power and Reclamation Service (Chisholm, 1930 and unpublished data kindly furnished) was in 1923, and the two lightest discharges were in 1919 and 1928. Correspondingly the proportion of outside catch to inside catch of salmon in the Minas system was greatest in 1923 and least in 1919 and 1928. This seems to indicate that a heavy movement of water (the upper layers) out of Minas basin in the spring when the salmon are approaching the surface results in a large proportion of the salmon being carried out into the bay of Fundy. As the salmon lives at different depths depending upon its condition and the physical factors that come into play, and as the movements of the various layers of water in sea water related to a river are very complicated, proper elucidation of this matter will be quite difficult.

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## Discussion

Mr. White (New Brunswick): Is there any possibility that the salmon are seeking water of lower salinity rather than being carried by the movement of the water? At the margin of the river they get a good catch, and you would have water of low salinity being held along the shores. With regard to your drift bottles, low salinity water rising to the surface would also be carried to the same places as your drift bottles, and it appears to me you have the same condition there—the salmon are seeking water of low salinity.

Dr. Huntsman: Mr. White's question would be answered in this way: At first I had hopes that such would be the case, and the local fishermen on the coast had the same idea, too, because they thought it best to put their gear near the brooks so as to get the benefit of the desire of the salmon to return to the fresh water. But they say they cannot see that the operation of the gear near those brooks is any more effective; indeed, they think it is perhaps not as effective as gear placed elsewhere. I have been similarly disappointed. I had the temperatures which would tend to give that low salinity, and no particular differences were observable between the shore and the middle of the bay which might indicate such a condition.

# THE SPAWNING PERIOD OF BROOK TROUT, *S. FONTINALIS*

H. C. White

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Brook trout are said to spawn earlier in the Northern part of their range than in the Southern part and this is, in general, undoubtedly true. However, facts which we have gathered during our investigations would indicate that the spawning period of trout is not related to the general temperatures but is more directly related to the temperatures of the spawning areas in their habitat.

In many regions of the rocky parts of the Maritime provinces of Canada where the surface soil is shallow, deep springs are scarce and stream temperatures fall rapidly with the coming of the cold weather and remain within a degree or two of the freezing point throughout the winter. In such streams the trout may spawn on the rapids instead of in the spring areas and consequently their eggs are subjected to a low temperature during the winter and early spring.

The low temperatures retard the development of the eggs and in order to have the fry in the free swimming stage when the temperatures rise in the spring, it is necessary for the trout to deposit their eggs at a relatively early period in the fall. Moreover, it seems probable that since low temperatures during certain of the early developmental stages of the eggs are detrimental, (Stockard 1921), the early deposition of the eggs is a provision for the passing of the eggs through the first stages of the development before the water drops to a low temperature. In such areas we have observed that the trout have a short spawning period extending from late September to the middle of October.

Prince Edward Island is situated to the North of many regions such as we have mentioned above and yet in that province we have found trout spawning during December and January. The spawning period there is very long, extending from late October till late January. (In 1933 the period extended into February). This long period seems to be related to the character of the spawning areas in the province. These areas are apparently suitable for incubation at any time of the year. The island is covered with a deep layer of porous soil and there are many large springs. The trout, as we have pointed out in a previous paper (White, 1930) select areas where the spring water enters through the gravel in the stream bed.

The spawning areas in all the streams we have examined on the Island were overcrowded with spawners and undoubtedly a few years ago when trout were more abundant there was even greater competition for the suitable spawning grounds. In January we have found in the spawning beds eyed eggs buried deeply in the gravel with newly deposited eggs in the upper layers.

In this region there is apparently a "Struggle for Existence" between the early spawners and the late spawners. The early spawners have the advantage of early developed fry which are able to take advantage of the abundant food supply as soon as they emerge from the gravel. However, the early spawners have the disadvantage of having many of their eggs dislodged from the gravel and eaten by those spawning later, (White 1930). On the other hand, the late spawners have the advantage of having their eggs undisturbed by other spawners but have the disadvantage of having their fry emerge at a later period than those which spawn earlier.

That the time of spawning is probably hereditary has been shown by the experiments carried out by Davis whose paper was presented before this society in 1931, (Davis 1931). He states that the development of a race of early spawners is, "one of the many improvements in our trout which we may confidently expect as the result of selective breeding." This is undoubtedly true as it applies to the strains of domestic trout which are being developed. When trout, which are to be reared for the market or reared to a legal size to be taken soon by anglers, are improved by selective breeding it is certainly a step forward in fish culture. But when we are dealing with trout which are intended *for establishing a breeding stock* in our natural waters, it seems probable, that without present knowledge of the requirements of the different waters, artificial selective breeding is more likely to be a disadvantage than an advantage.

Our observations indicate that the time of spawning is an adaptation of trout to their habitat and undoubtedly there are other specific adaptations. Ignorance of the histories of the various strains of trout and of the requirements of the streams to be stocked may be causes for many of the failures to establish a breeding stock of trout in depleted waters.

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## Discussion

Mr. Rodd: In your observations have you found anything similar to Dr. Mottley's findings that domesticated stock will take on the characteristics of the native stock in one or two generations?

Mr. White: That is where they are mixed with the native stock. There are two possibilities. They may be so unfitted for their environment that the trout introduced all disappear and the other trout predominate. Or the factors which are predominant in the indigenous trout may overshadow the factors in the introduced trout.

Mr. Rodd: Environment would be likely to bring them all to the same level?

Dr. M'Gonigle: Not environment directly. Of course we are getting to a debatable point there, whether environment affects the trout. But it may be that the derivatory characters in the indigenous fish are dominant factors and that you do not see the other factors where they cross with the other trout.

Dr. Greeley: May I ask Mr. White what was the lowest temperature at which he found trout spawning? I know he reported in 1930 that around 40° was the temperature he found spawning; did you get them any lower than that?

Mr. White: In the spring water in Prince Edward Island the spawning water is always at the same temperature; that is, the spring water does not change. In the shallow streams they spawn early before the temperature has dropped. I do not know the exact temperature.

Dr. Greeley: In relation to hereditary vs. environmental factors in the time of spawning, may I mention that in western Michigan the rainbow trout is of the steelhead type, migratory into lake Michigan, and it generally spawns in the spring. As far as I know it is all one race; at least it is an introduced species there and has not had a chance for generations and generations of selection to bring about different times of spawning. And yet in the spring of 1932, in the Little Manistee River system the rainbows began spawning along in January, so that in the spring of that year they were fry as large as brook trout fry that were spawned that fall. At the same time other rainbows were still spawning in the river, whereas in other larger rivers such as the Big Manistee the run did not commence in the winter at all so far as we could learn. Of course that is nothing new there; it is just a case of a run started by a rather warm temperature during the winter. But it does show that even where there is no apparent hereditary basis you get a long spawning season of trout.

Mr. Dinsmore: Do I understand the author to say that temperature controls the spawning season?

Mr. White: Not the general temperatures. I am speaking now of indigenous trout, not interfered with in any way, shape or form, so that their spawning period must be related to the temperature of their spawning grounds.

Mr. Dinsmore: Is there a difference in the age at which indigenous fish spawn in the same waters?

Mr. White: Yes—indigenous fish in the same waters.

Mr. Dinsmore: What I had in mind was the relation between two year old and three year old indigenous trout spawning in the same area.

Mr. White: I cannot answer that question.

Mr. Dinsmore: Dr. Davis and I have discussed that question. I may say that beginning next week we shall be taking eggs from our oldest fish, about four years of age and weighing four to five pounds. Ten days to two weeks later

we will begin to take eggs from our two year old fish, and about the first of November we will begin taking eggs from our yearling fish. Our native stock will be two weeks older than the fish bred directly from the commercial stock.

Mr. Charles O. Hayford: I am taking out of the domesticated stock our selected breeders at Hackettstown. We started in 1919—that was the first; and by taking the eggs from early spawners we have in a period of about twelve years set the spawning period ahead by fifteen days. In 1921 our fish spawned around November 10th. They were kept under the same conditions, each generation down to the present time, and by selective breeding we have set the time of spawning ahead to October 25th.

Mr. White: I am not speaking of trout which are intended to be marked or tagged shortly after they are planted; I am speaking entirely of trout which are intended for the establishment of breeding stock.

Mr. Langlois: May I add a comment about another species, which may have some relation to the same problem. In one of our ponds we had some rock bass adults which had been held over for breeders. As the breeding season approached we brought in a second stock of rock bass from another place and put them in an adjacent pond. The rock bass were practically all the same size, but the ones that had been held in that pond spawned nearly a month earlier than the ones which were brought in from another place and put in an adjacent pond where the temperatures were quite similar. You might conclude that their spawning was determined not so much by the actual temperatures which prevailed when they spawned as by the conditions to which they had been subjected in advance of the spawning season.

Mr. Rodd: It might not be out of order to refer to Maligne Lake in Jasper Park as an example of outstanding success in the introduction of speckled trout. The stock introduced was domesticated stock which had been in captivity and under artificial conditions for many years. These fish, introduced into Alberta from Pennsylvania, reproduced remarkably well, affording excellent sport.

Mr. Catt (New Brunswick): We have in the maritime provinces waters populated by selected, quick-growing trout of hatchery stock. Hart Lake, at the head of the Wallace River, carries this stock, and the fish are exceptionally fine. They are better than the wild sea run strain to be found below the eighty foot barrier fall on the lake's outlet. Similarly Woodard's Lake, not far from St. Andrews, New Brunswick, has produced fish which in three years attained almost four pounds in weight, and that, both from a game and a table viewpoint, could hardly be surpassed.

# SOME FACTS AND THEORIES CONCERNING THE ATLANTIC SALMON

H. C. White

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There has probably been more written about the life history of the Atlantic salmon than about that of any other fish. Some of the writings are acknowledged fiction, some theoretical, some scientific and some which must be classed as pseudo-scientific. In this paper we shall present some data from our own observations and advance certain theories which seem to explain phases of the behavior of migrating salmon.

For a number of years we have been making observations on the Atlantic salmon in parts of Prince Edward Island, New Brunswick and Nova Scotia. Our observations, however, have been largely centered in Cumberland County, N. S. at Apple River on two streams which drain into a common estuary of the Bay of Fundy. These two streams which are known as the East and West branches of Apple River are very similar in volume of flow, temperatures and other physical characters and also in their faunas.

When we first visited these streams in 1931, we were surprised to learn that within recent years no adult salmon were known to ascend the East branch to spawn but that all the spawning salmon which entered the common estuary ascended the West branch. At that time there were no barriers to the migrating salmon on either branch but some ten years previously there had been a mill dam at the head of tide water on the East branch. A fish-way had been placed in this dam but no salmon were ever known to have passed through it. Some sixty years ago when there was no dam on this branch, many salmon ascended it to spawn, but after the dam had been out for ten years there was no run of salmon in this stream. However in the late summer and fall, many salmon would follow the tide up the estuary of this branch to the head of tide water and would go back down the estuary with the ebbing tide. This behavior is not peculiar to this stream but occurs in many small streams which the salmon ascend as well as streams which they do not ascend.

Since salmon are not known to ascend small streams to determine their suitability as spawning and rearing areas, it would seem that they are able to determine this without ascending the stream. This might be accomplished by taste or smell or some other sense. In the two branches of Apple River the main difference we found was the presence of many young salmon in the West branch and their absence in the East branch.

Is the presence of young salmon in a stream a factor which causes adult salmon to select the stream for spawning?

All male parr over one year of age and also many fry-of-the-year in these streams become sexually mature in the early fall, and since the milt from these is evidently shed into the stream, it is possible that the milt in the water is the substance which reacts on the sense organs of the adult salmon at the mouth of the stream. That this milt is unsuitable for fertilization we have demonstrated in an experiment carried out at Forbes Creek some years ago. It was found that when the milt from parr was mixed with ripe ova, a fairly high fertility was secured but 60 per cent of the resulting fry were deformed or were eyeless monsters. A check using ova from the same female but milt from a mature adult male gave normal results.

During our trout experiments at Forbes Creek, several hundred salmon parr, reared in an enclosure during the summer were liberated in the fall. The following year many of these parr were still in the region where they were liberated and that fall when the male parr were sexually mature, three adult salmon ascended the stream to this area. That was the only time during our investigations there that adult salmon were found in that area.

In accordance with our theory, we predicted that if young salmon were introduced into the East branch of Apple River, the adult salmon would enter this stream to spawn. In the summer of 1932, twenty-five thousand salmon fry were carefully planted in the lower part of this stream and there was a good survival from these. That fall, as we had predicted, a run of salmon entered the East branch. The following spring there was an abundance of salmon fry from the spawning of these salmon and in the fall of 1933 there was another good run of adult salmon.

When making the planting of salmon on this stream we distributed about three hundred fry in a very small branch stream and the spawning salmon ascended even this rivulet.

The theory that the presence of salmon parr in a stream is a factor which causes the adult salmon to select the stream, has, we believe, the following points in its favor:

(1) No better criterion of the existence of suitable spawning and rearing areas could be selected by the adult salmon than the presence of parr in the stream.

(2) It predicts a rational use for the large quantities of milt shed by the parr.

(3) If the presence of parr above a barrier could be detected in the water coming over the barrier, it would indicate to the salmon that the barrier could be surmounted.

Such a theory is not a refutation of the "parent stream theory" but may be an explanation of that theory. Our tagging operations at Apple River show that the adult salmon, returning for the second time to spawn, may not only return to their own stream but to the identical pool which they occupied the previous year. However, many salmon in the sea become strays and as the spawning time approaches these

salmon endeavor to find suitable spawning streams. It is these salmon, we believe, which enter the estuaries of various streams. At Apple River, the formation of the common estuary of the two streams and the high Fundy tides rushing in and out, tend to form a maze which confuses the local migrating salmon but incidentally made unique conditions for making observations on their behavior.

In conclusion, we may state that we consider the submitting of these theories at this time as premature, since further experiments and observations are required. We are presenting them now, however, in the hope that other observers will confirm or refute them.

## Discussion

Mr. Dinsmore: I have been exceedingly interested in this paper. I want to add to it an experience we had on the Pacific coast with the sockeye salmon, which demonstrates very clearly that the sockeye salmon has the same homing instincts as the author's paper shows to be true of the Atlantic salmon.

About thirty years ago we undertook to demonstrate to the fishermen on Puget Sound, who said that the sockeye salmon must reach lakes fed by ice water from the glaciers, that this was not necessary in order for them to deposit their eggs. Fish were taken from the Fraser River run at Point Roberts and towed into a fresh water lagoon at a point not far from the Canadian boundary near Blaine, Washington. The towing of the fish was almost a failure because of certain difficulties which arose in connection with the carrying out of our plans as originally arranged, but we did produce from the fish impounded there seventy-five thousand eggs. These fish were moved to a tributary stream on the Skagit River, Washington, a stream which almost never received a sockeye salmon. The eggs were hatched there and planted in this stream on the Skagit—the salmon run on the Skagit, as you who are familiar with the Pacific salmon know, is distinct from the run on the Fraser River. I am not able to say from memory just what year they came back, but at the proper return year two hundred thousand eggs were taken from salmon which entered Bradley Creek, a creek which never in the memory of the white man had had a run of sockeye salmon before.

Mr. Catt (New Brunswick): A rather interesting observation has been made on one of the streams in Albert County, New Brunswick. The mouth of the stream has been obstructed by a dam which absolutely prevents the ascent of salmon. There is no means of the fish getting past the tide, which goes up to the foot of the dam, and there is no spawning ground below. There are no young salmon up above it. I was talking this over with Dr. M'Gonigle and he suggested that possibly some of the stream inhabitants, which would include rainbow trout, might come into the picture.

# CAN BLOOD SUCKERS AFFECT THE FISH POPULATION OF A LAKE?

HERBERT JOHNSTON

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In the summer of 1932 the lake inspectors noticed that blood suckers were plentiful in Macaulay's lakes, Argenteuil County, Range V. One fish was caught alive and preserved in formaldehyde. As the fish, a sucker, was dying two blood suckers came out of the anal orifice.

This summer Mr. Macaulay wrote that the stocking program of 10,000 fry in three years was unsatisfactory. The inspectors returned to Macaulay's lakes and again it was forced upon their attention that the blood suckers were prominent in the lake. The important question is: Did the blood suckers kill off the trout in such numbers as to make it appear that the lake was never stocked at all?

Our data concerning the detrimental effects of blood suckers consists of the following:

(1) The incident mentioned above shows that blood suckers can get into a fish by way of the anal orifice. And there, in contact with the soft tissues, we might easily suppose that several suckers could suck enough blood from a fish to kill it.

(2) Observation made at Payne's Lake near Labelle: A two and a half inch minnow was seen sinking helplessly to the bottom of the lake with a blood sucker wound around it. Obviously the minnow was doomed. If such a thing could happen to a minnow, then it could just as easily happen to a fingerling trout.

(3) Observation made near Lake L'Achigan: A two inch tadpole was seen dead near the shore of a small lake with two blood suckers attached. Perhaps the blood suckers attached themselves to a dead tadpole, but the observations made above indicate that the blood suckers go after living material for food. So it seems logical to suppose that the blood suckers went after a living tadpole and killed it.

# THE PROBLEM OF CONTROL IN AQUICULTURE

A. G. Huntsman

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How many times has the desire been born to repeat in the water a fair amount at least of the success that has been attained by man in tilling the land and in raising stock animals! Time after time have hopes been raised and then dashed to the ground. Why has aquiculture been so backward as compared with agriculture? Manifestly because of the much greater difficulty in controlling the conditions in water than in doing so on land.

In our efforts have we, perhaps, in many instances, been trying to run when we have scarcely got beyond the creeping stage? Positive achievements there are that are comparable to agriculture, such as the pond culture of carp and trout. Also there have been very successful introductions of fish into certain natural waters, that happened to possess everything necessary but the fish. Further progress seems dependent upon the extension of our use of the two factors thus illustrated. On the one hand we should attempt the control of larger and larger bodies of water, starting with small ponds; and on the other hand we should take advantage of particularly favorable natural conditions that we may be successful in discovering.

Both of these methods of progress presuppose knowledge of the conditions that are necessary. Such knowledge is as yet very incomplete, so that progress is very slow. We need a definite program of investigation to acquire such knowledge. We can express in two ways the general question that must be answered, taking for example the desire to have more trout:

(1) What are the conditions that trout require? This is the simple and direct way of putting it, and some may believe they already have the answer or answers to that question. Let them be put to the test of predicting what will happen to trout under the varied conditions that obtain in nature, and deficiencies in their knowledge will soon be apparent.

(2) The other way of putting the question definitely brings in the failures in practical attempts to provide more trout. What are the conditions or factors that cause death in trout?

There is no difficulty in getting sufficient trout embryos. The difficulty lies in keeping them alive till they become full grown fish. If we ascertain the reasons for the various deaths that occur in a stock of trout, we will be well along toward our goal; but the problems presented by these deaths will tax our keenest intellects. If the small trout disappear and they are found in the stomachs of the large ones, there is an obvious inference and an obvious course

of action,—large trout eat the small ones, and, to prevent this, the sizes should be separated.

Actually the problem may be much more complicated. If the large trout are well fed, they may not attack the small ones, and the latter, if in good condition or with suitable shelter, may elude the former. There may thus be an alternative to segregation of the sizes.

Another case would be to find the trout dead and with fungus growing on parts of the body. The obvious inference is that the fungus killed the fish, and should be eliminated by treating the live fish with a salt bath. Actually the fungus may have grown only after epidermal cells were weakened by a bacterial infection, and the bacteria may have been able to invade the fish only when the latter had its vitality lowered by high temperature, low oxygen content of the water, or unfavorable acidity of the water.

Incomplete knowledge may result in the treatment of symptoms rather than in the elimination of the underlying causes that are bringing about the death of the trout. It is very desirable that the investigator should himself attempt to rear the fish under the conditions that have resulted in the death in question.

The matter is further complicated by conditions varying from one locality to another, and from one season to another. When a certain factor, such as temperature, is seen as probably a cause of mortality, the investigator should devise carefully controlled experiments so as to accurately determine the gradation in unfavorable action that is bound to occur. When a condition is only slightly unfavorable, its effects, perhaps slowly produced, are apt to be overlooked.

Given a knowledge of the conditions to be provided or avoided, how can we proceed most rapidly? Some fish can be reared satisfactorily in confinement by buying food for them and feeding them regularly, but this is costly. The real problem is to produce their food in the water, so that they may be "turned out to pasture" and so reduce the expense. Such will be real aquiculture.

The natives of this part of the world were found by Europeans to have a very primitive type of agriculture compared with what exists here today. They removed the trees from a plot of ground, planted their corn, and reaped it. But when, in the course of time, the ground became choked with weeds, they moved on to a new place. We may follow rather similar methods for the water; for example, find a body of water that without very great difficulty can be made to yield some fish that we desire, and, when it ceases to be productive, repeat the experience in another place. This method may consist in the mere exploitation of the fish found in the place, in the introduction of new fish that do well for a time, or in the flooding of more land so as to provide more and better feeding grounds for the fish. In any event it does not go very far toward the desired goal.

In the early days agriculture was farthest ahead in regions where control of weeds and moisture was easiest. In districts where the climate was so dry as to kill all weeds, and where a river periodically overflowed its banks or could readily be diverted to irrigate the dry soil, it was a comparatively simple matter to plant and reap successfully.

Should we not follow agriculture, and, for a start, look for places which have no water "weeds" and which can be flooded at will with water? If this is done, we can repeatedly start from scratch. When the area is land, aquatic life will disappear. Then, when it is again covered with water, such forms of life as are desired can be put in the water, and will have an opportunity of growing without interference by undesirable forms. In the course of time some of the latter will gain access to the water in some way or another, and may then be removed by draining and permitting the ground to be occupied by land plants.

These land plants would seem able to play a very important role in producing quantities of fish. Water alone is not sufficient for the growth of the various microscopic and macroscopic plants, on which the aquatic animals are to feed. Fertilizing salts, such as nitrates and phosphates must be provided. Such may be supplied in the form of commercial fertilizers, but it is better to have them added to the water steadily and in small quantities, for example by the slow decomposition of vegetable humus or similar material. If the bottom of the water is covered with decomposing material of this nature, and, if there is a circulation that will bring the fertilizing salts from the bottom as set free there, toward the surface where there is light, a steady growth of plants is possible in the upper layers of the water.

One of the surest methods of providing such a supply of nutrient salts for the aquatic vegetable organisms is to flood an area that is covered with a dense growth of land plants that contain nutrient salts brought from the depths of the soil. These will be killed by the water, and, if of varied nature, as they are likely to be, they will decompose at various rates, and, if of varied height, they will set free the nutrient salts at various levels in the water, thus ensuring throughout the water and for a considerable time the substances needed for growth by the aquatic life. While the higher plants, that live in the water, and send their roots into the bottom, doubtless function in the same fashion when they die, it should be possible to have a much greater and more precise effect by growing land plants and then flooding.

Much experimentation and study will be required to make such an alternation of two such different growths (land and water) both rapid and effective, but the possibilities for a successful aquiculture are very great.

To conclude, it is our contention that the central problem of aqui-

culture is how to control the conditions in the water, and that progress toward such control can best be made by a combination of three lines of investigation, to answer the questions that follow:

(1) What are the conditions required by the particular fish or forms of aquatic life which it is desired to grow; or, better, what are the factors which bring about their death, and which must be avoided?

(2) Where are there areas which can at will, and with moderate expense, be alternately flooded with water and allowed to revert to land conditions?

(3) How can the nutrient salts required by aquatic vegetable organisms be furnished most effectively and cheaply?

Answer to the first of these gives the directions in which control is to be exerted, answer to the second gives locations where control is possible, and answer to the third gives the means of ensuring quantity production.

## Discussion

Mr. Richardson: I would like to point out to Dr. Huntsman that one must not neglect the mechanical features which develop in the flooding of land. I cannot from my own experience speak for the chemical side, but unquestionably the mechanical features are important, such as destruction by the action of waves and ice and dead timber. In many cases, for example, there is a scouring of the shore, resulting in a very poor class of shore margin, and there is also the significance of the development of swamp areas. So I think you will find it very advantageous to pay some attention to the mechanical as well as the chemical aspects of the question.

Mr Rodd: What Dr. Huntsman is really doing is laying down a plan of investigation with a view to starting and continuing on a proper basis so as to reap annually the best and most valuable crops that the various types of water will produce.

# SOME SUGGESTIONS CONCERNING THE INTRODUCTION OF SOME RUSSIAN FISHES IN CANADIAN WATERS

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The bodies of fresh water in Canada are in many respects similar to those of Northern Russia; there are many large lakes and rivers with clear, unpolluted waters, frozen over in winter and cool in summer time. They are well populated with American game fishes of the family Salmonidae—such as salmon and trout. There are also several commercial fishes of the family Coregonidae such as the whitefish, but some very valuable fishes which are common in the northern provinces of Russia are missing in America. They might be easily introduced and acclimatized in Canadian waters. At any rate attempts to introduce them might be considered worth while, would present considerable interest and might prove profitable in the future.

The first of these fishes to be mentioned is a sturgeon of small size (*Acipenser ruthenus*, Linné), a delicious fish which is abundant in such Russian rivers as the Volga, Kama, Oka, N. Dvina, Don, Dnieper, and is also known from the Dunai River. This small sturgeon averages from two to three feet in length and weighs from two to three pounds. It is propagated artificially at the Volga River, where a great many young sturgeon are caught and sold. Its fry and young stages are very hardy and can be transported easily for long distances. The young, after being placed in small lakes and ponds thrive and grow very well as was demonstrated by the late Dr. O. Grimm, a distinguished Russian fish culturist, in his long years of experiments made in the ponds of the Nikols Fish Hatchery, in the province of Novgorod. It is true that this sturgeon, which spawns in rivers, does not propagate in closed waters but it grows very well in suitable ponds.

There is also a small sized, but prolific and commercially important fish belonging to the *Coregonidae* family, namely *Coregonus albula* Linn. living in the lakes of Northern Russia, Estonia, Latvia and Finland and missing in Canada. This small fish (size 3/8 inches) is particularly abundant in the Lake Pskovskoye (on the boundary between Russia and Estonia) and in the lakes of Finland, where it presents an important article of winter under-ice fishing. The fish is of excellent taste and is sold mostly in frozen state in winter time.

Finally there are a few representatives of commercial cyprinid fishes which are absent from Canadian waters and which could be introduced from Europe. (1) Bream (*Abramis brama* Linné) which reaches a weight of five pounds and is a good game fish as well as commercial. It lives in deep lakes. (2) Crucian carp (*Carassius carassius* Linné) size eight to twelve inches, weighing from one-half to two pounds. (3) Tench (*Tinca tinca* Linné) of about the same size. The last two

of these species thrive in shallow, marshy lakes and ponds and are hardy fishes, capable of living in water of low oxygen content and of remaining alive, covered with bottom mud, in freezing temperatures. Their capacity for living in shallow and marshy waters, sometimes overcrowded with water plants, makes them a most suitable fish for stocking small farm ponds and marshes. Suitable for pan frying they are the commonest fish on the peasant's table in Russia and neighboring European countries.

I can recommend these last two cyprinid fishes as most desirable for introduction in small Canadian lakes and farm ponds. They propagate very easily in any natural or artificial shallow ponds. Both sexes can be purchased for introduction on the fresh water fish markets at one of the Baltic ports of Germany, Latvia or Estonia and can be easily delivered by one of the transatlantic steamers in barrels; being placed in a suitable pond they will spawn in the month of June or July and produce fry, which at the end of the summer become fingerlings; they can be grown up in any desirable quantity for distribution in the farmer's ponds and selected small lakes.

Of course, the first steps in the matter of introduction into the country of a new kind of fish must be made by the government after considering the question thoroughly by the experts in ichthyology and fish culture, because even a trial transportation of imported fishes is connected with expenses and the experiment must be made under government's control, and at the beginning the planting must be made in selected and controlled waters.

# RELATIONSHIP OF AQUATIC PLANTS TO OXYGEN SUPPLY, AND THEIR BEARING ON FISH LIFE

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The data presented in this paper were gathered during the course of our regular 1934 summer investigations. For the most part the information has been the result of our work on one lake in central Ohio, Buckeye Lake. Several other lakes in the state were studied, and as the findings agree in general with Buckeye Lake data, further mention will not be made of them.

Buckeye Lake is an artificial lake covering nearly four thousand acres. It was built one hundred years ago to supply water for the Ohio and Erie canals. Since the canals went out of existence it has been used exclusively as a pleasure resort.

The character of the country surrounding the lake varies considerably. The central and western portions are surrounded by flat meadow land or low rolling hills, whereas the eastern tip is flanked by high, rugged hills.

The depth of the lake varies from between ten and fifteen feet in the central and western portions to a maximum of six feet in the eastern end, except where it was artificially dredged in order to permit the passage of boats.

The operations of the dredge, contrary to expectations, was of little value in keeping a channel open for boats. The channels were not deep enough to keep down the vegetation and due to the construction of the dredge, materials from the bottom were necessarily emptied again into the water along the edge of the channel just dug. This further reduced the depth of the water at these places and cattails, rushes and other aquatic vegetation have gained a foothold.

This combination of the original shallowness of the eastern end of the lake, the protection from wind and waves it receives from its rugged shoreline and from the cattails and rushes growing on the embankments thrown up by the dredge, make it an ideal habitat for the growth of gross aquatic vegetation.

The vegetation on the extreme western edge of the heavily vegetated area, where it may from time to time receive some wind action, is composed of the rooted submerged type, *Myriophyllum spicatum* (water milfoil or fanwort), with some plants of the water weed, *Elodea*. These rooted plants are further protected from the open lake by two heavy growths of *Lotus* lilies which reach out toward each other from opposite shores.

Inside this protective fringe of rooted vegetation is an almost pure

culture of a "moss" which seldom, if ever, roots. This submerged plant has many names the most common of which are probably "coontail" moss and hornwort. It is known to the botanist as *Ceratophyllum demersum.* It is so abundant in this portion of the lake that it is almost impossible to row a boat through it.

Because of the low stage of water (the lake ranged from 13 to 19 inches below normal during the month of July when the samples were taken) and the exceedingly high temperatures which prevailed during this time, combined with the fact that the submerged vegetation served as an anchor, there was an exceptionally heavy growth of a surface vegetation over this entire area. Over 99 per cent of this surface vegetation was the small duckweed known as *Wolffia punctata.* The reremaining one per cent was made up of *Wolffia columbiana, Spirodela polyrhiza, Lemna minor,* and *Lemna triscula.*

Throughout the entire lake over 200 oxygen samples were taken from 47 sampling stations. Eighteen of the sampling stations were located in the eastern tip of the lake, amidst the matted vegetation, and from them over 100 oxygen samples were taken.

Many natural and artificial phenomena working together or separately cause corresponding changes in the oxygen content of water. Samples taken from the same place in a body of water on successive days at the same time of day and in the same way may look like samples taken from entirely different bodies of water.

The quantity and movements of the microscopic plants and submicroscopic animals usually affects the oxygen content of the water. A gradual change in the temperature of the water also seems to cause a gradual change in the oxygen content, especially of the surface water. A sudden change in the air temperature may chill the surface water causing convection currents in the water which may upset the supposed oxygen content. Wind and waves have their effect. The kind of day, whether sunny or cloudy also affects the quantity of oxygen. The depth at which the sample was taken influences the amount of oxygen. The nearness to the bottom, especially in new artificial lakes, is still another factor. Similarly if there is any quantity of decaying organic matter in the water it may cause a corresponding drop in the oxygen content of that water.

Despite all these upsetting factors, if a sufficient number of samples are taken a general estimate can be made as to the quantity of oxygen present in a given body of water at a given time.

It has been shown by many investigators that dissolved oxygen is usually lowest at daybreak because at that time there has been a period of several hours during which the photosynthetic action of plants in the water has been suspended, and they have hence made no oxygen but instead have drawn on what oxygen was already available, for respiratory functions.

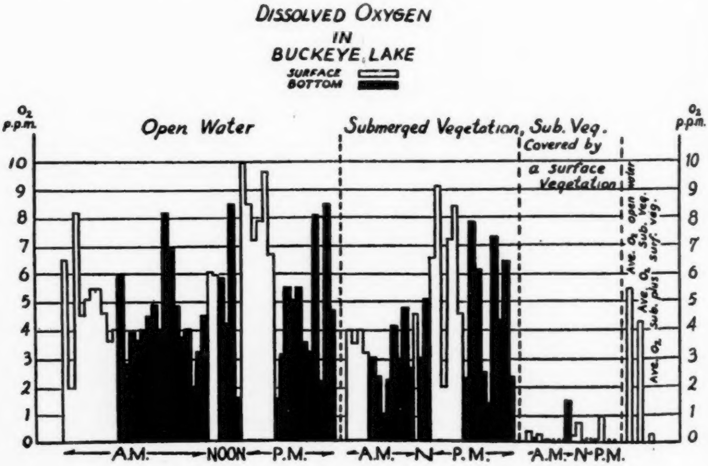
If a dark night is followed by a dark, cloudy day the low oxygen at daybreak is not increased but is rather further drawn on because

there is little or no sunlight to produce further photosynthesis in the plants. If this cloudy day is a stormy, cold, day during which the surface water may become chilled and thus increase in weight and sink toward the bottom forcing up the bottom water which is normally low in oxygen, the result can readily be seen.

In the accompanying graphs, showing the dissolved oxygen in Buckeye Lake, the oxygen has been plotted in three time groups. All oxygen samples taken between 6:30 and 10:30 A. M. are placed in the A. M. groups, all samples taken between 10:30 A. M. and 1:30 P. M. are placed in the Noon group, and all samples taken between 1:30 and 6:30 P. M. are placed in the P. M. group.

The oxygen has been plotted for both the surface and the bottom water in (1) open water, where no coarse vegetation was in evidence, (2) water with abundant (choked) submerged vegetation (mostly *Ceratophyllum*) and (3) water with abundant submerged vegetation and covered with a surface vegetation (mostly *Wolffia punctata*). It has been estimated by Dr. Lawrence E. Hicks of the United States Soil Erosion Service that over a million of these small *Wolffias* cover a square yard of water.

Examination of the graph giving the dissolved oxygen in the open water shows the tremendous variation in the quantity of oxygen in the same lake on different days during the same month. It also indicates that the amount of oxygen in the surface water is greater than that in the bottom water and tends to show that the average amount of oxygen is greater in the P. M. samples than during any other time of day.

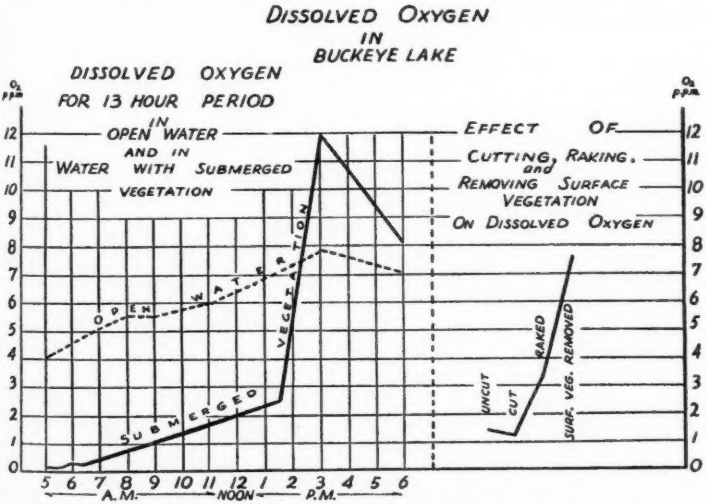


Examination of the graphs illustrating the amount of oxygen in water choked with submerged vegetation shows the same marked variations in the daily samples. These graphs also show the increase in oxygen during the noon and P. M. samples over the A. M. samples. The bottom oxygen, of course, generally falls below that of the surface.

The graphs indicating the dissolved oxygen in water choked with submerged vegetation and covered with the surface vegetation are scanty but interesting. The same general rise in amount of oxygen is noticeable in the P. M. over the A. M. and Noon samples. In every case but one, the surface oxygen is higher than that of the bottom. The average of all samples taken under the surface vegetation in protected areas however, was only 0.2 ppm.

In a few areas where the breezes had a chance to ripple the water, samples were taken to determine the amount of oxygen under surface vegetation which was not so protected from the wind action. The average oxygen mounted to slightly over 2 ppm. This is another point in favor of removing the embankments thrown up by the dredge whereon cattails and rushes now abound.

Averages have been made of all dissolved oxygen in these three situations and the data are presented graphically. The average quantity of dissolved oxygen in the open water amounted to 5.5 ppm., as opposed to about 4.3 ppm. in water choked with submerged vegetation and 0.2 ppm. in water choked with submerged vegetation and covered with surface vegetation.




The graph showing the amount of dissolved oxygen for a thirteen

hour period in open water as compared to water with submerged vegetation presents some interesting information. The fundamental similarities in the rise and fall of oxygen in both situations are to be noted, a low point being noticeable at daybreak (about 5 A. M.) and a high point at 3 P. M. The difference in the minimum and maximum quantities of oxygen in the vegetation are extreme. At daybreak the oxygen ranged between one tenth to fifteen hundredths parts per million. In the middle of the afternoon the dissolved oxygen had risen to twelve parts per million.

The effect of the night on dissolved oxygen in the vegetated areas is evident. If the conditions of the night were to be continued by a dark cloudy day the results on fish life are obvious. As it were many fish were observed swimming at the surface of the water during the time these morning samples were taken. It so happened that some open water was available for them at the surface.

On the evening of July 26, between 5 and 7 P. M., there was a very strong wind and a hard rain-storm and much of the submerged and floating vegetation above the town of Thornport was carried into the only remaining open channel and a number of the open pools. This closed the surface water of part of the channel and many of the pools. The next morning 412 dead fish were found floating in the tangled mass of submerged and surface vegetation where their struggles to get to the surface water had obviously taken them. The species and numbers taken in the closed channel, estimated at 500 feet in length and 25 feet wide, are as follows:

354 adult gizzard shad (*Dorosoma cepedianum*)
30 yearling to adult bluegills (*Helioperca incisor*)
10 adult lake chubsuckers (*Erimyzon succetta kennerlii*)
10 yearling to adult brown bullheads (*Ameiurs nebulosus nebulosus*)
2 yearling mud pickerel (*Esox vermiculatus*)
2 yearling carp (*Cyprinus carpio*)
1 adult johnny darter (*Boleosoma nigrum nigrum*)
1 adult Iowa darter (*Poecilichthys exilis*)
1 adult tadpole catfish (*Schilbeodes gyrinus*)
1 yearling white crappie (*Pomoxis annularis*)

On the same morning at Edgewater Beach, in a similar closed channel estimated at 600 feet in length and 40 feet wide, 104 dead fish were found. These consisted of 87 gizzard shad, 14 adult bluegills, 3 adult pumpkinseed sunfish, *Eupomotis gibbosus,* and 3 adult lake chubsuckers.

On July 11th at the extreme eastern end of Maple Swamp Sanctuary in an area estimated at 300 feet long and 50 feet wide, choked with surface and submerged vegetation, we picked up the following dead fish:

100 yearling to adult bluegills
25 yearling to adult yellow perch (*Perca flavescens*)
1 adult green sunfish (*Apomotis cyanellus*)
1 yearling largemouth black bass (*Aplites salmoides*)

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Figure 1
Ohio's equipment for removing vegetation.

UNIV. OF MICH.

On July 10th below Thornport in a closed channel approximately one-half mile long, we counted over 100 dead adult gizzard shad.

On July 10th in front of Edgewater, in an area about 50 feet square and choked with submerged and floating vegetation, we enumerated 57 dead fish. Of this number 32 were yearling to adult yellow perch, 21 yearling to adult bluegills, 3 adult pumpkinseeds and 1 adult lake chubsucker.

Practically all dead fish were colored pink on the upper surface and decomposed rapidly. How many fish were killed during the summer is not known because we were working on a method of control and circumstances did not permit full time at the project.

There is little doubt but that the abnormal oxygen depletion in the vegetated area is due to the extra consumption by the plants themselves at night. Biochemical oxygen demand tests, made by the State Health Laboratory, show very little difference between the waters of the east end of the lake (amidst the heavy vegetation) and those of the west end. They tested respectively 4.5 and 5.7 parts per million. Biochemical oxygen demand tests are designed, of course, to determine the amount of oxygen necessary to completely oxidize any available organic matter in the water.

A very practical application has been made of these findings A paddle wheel power boat (Figure 1) with a shallow draft and fitted with a cutter bar which can be regulated to cut (within limits) the vegetation at any desired depth has been used for several years by the Ohio Division of Conservation to keep channels clear for boats. Our data indicate that cutting this non-rooted vegetation is of little value in killing the vegetation and, as far as permitting boats to pass through it is concerned, conditions were as bad after cutting as before. Also, as the vegetation is a non-rooting type, cutting tends to increase the number of growing plants in the water which consequently may further reduce the amount of available oxygen in the water. (See graph entitled "Effect of Cutting, Raking and Removing Surface Vegetation on Dissolved Oxygen," which has been made up of data obtained from one station.)

Consequently the cutter bar was removed from the "moss cutter" and a long "two by twelve" plank, fitted with half inch iron bars which could be lowered into the water for a depth of eighteen inches, was bolted onto the lever arm in its place. For about six weeks, two eight-hour shifts were busy with this rake removing the vegetation. Oxygen samples indicate an almost immediate rise, however, a thick scum of the surface vegetation remained on the surface so a skimmer made of window screening was devised to hook onto the rake. Oxygen rose to about 7.75 parts per million after the surface vegetation was removed. All these samples were taken at the same station at about the same time of day. The removal of submerged vegetation allowed the use of row and motor boats, although for fish life the floating duckweed must be removed.

In closing we desire to point out that spawning conditions for pond or lake fishes during March, April, May and June may be ideal and result in a good hatch of fish, but if there is shallow water, rearing grounds may develop a choked condition of submerged aquatic vegetation, particularly hornwort, together with a mat of floating vegetation, especially *Wolffia punctata* (one million or more per square yard) which seems to be correlated with oxygen depletion, fish mortality, and in some cases cutting off the potential food supply.

## Discussion

Mr. Wickliff: I would like to add that the results of this work are very similar to those presented by R. L. Barney and B. J. Anson of the United States Bureau of Fisheries, at the meeting of the American Fisheries Society held in Ottawa in 1920. It is also interesting to note that in a book on the vegetation of Buckeye Lake, written in 1912 by Frederica Detmers, it was predicted that in a few years the eastern end of Buckeye Lake would be filled with vegetation. The eastern end of Buckeye Lake is actually filling up with vegetation, and unless something can be done to control it I am afraid it will be a case of farming in the east end rather than fishing. By the use of the rake we devised this summer we have certainly saved a number of fish, and also have temporarily met the criticisms of people at the eastern end who had taken out licenses for boats and could not move their boats from the docks because of this excessive vegetation.

A publication by Dr. David H. Thompson, of the Illinois Natural History Survey, states that the critical point for most fishes in the matter of oxygen content is probably about 2.5 ppm. It is interesting to note that according to the graph shown by Mr. Roach, at about five-thirty in the morning the oxygen content at the surface of the water was less than one part per million; I believe in some cases it was as low as .15 of one part per million. How these fish could survive I do not know, unless the act of swimming at the surface causes a certain movement of the water which aerates it and the fish are able to breathe; or possibly the fish take the air and the water into the gills and are able to exist for a period of time, at least until ten or twelve o'clock in the morning when the oxygen content goes above what is said to be the critical point. But here is an actual case of fish surviving for several hours with an oxygen content ranging from .15 to 2.00 ppm. at the surface. We were taking the oxygen content while the fish were swimming at the surface, and they did not die.

Mr. Markus: I would like to ask what time of the year or during what part of the summer these low oxygen contents occurred? Was it during the entire summer, or just part of the summer?

Mr. Wickliff: July and August.

Mr. Markus: How do you account for these low oxygen contents at that time and not earlier in the summer?

Mr. Wickliff: We did not make any oxygen tests prior to that time. The people at the eastern end of the lake kept sending in letters for relief. We re-

quire them to have a one-dollar license for the use of each rowboat. These licensees had taken out several hundred permits for their boats, and the vegetation prevented them from using the boats. As a result of their complaints we were sent to the lake to conduct an investigation with a view to finding out how to relieve the situation, and we ran into these very interesting problems. We did not have information prior to the fifth of July.

MR. MARKUS: What occurred before that you do not know.

MR. WICKLIFF: But there is another point; the vegetation prior to that time was not so dense.

MR. MARKUS: Usually the greatest depletion occurs in the fall, and I am wondering how to account for that unless it is a question of decomposition at that time of the year when the vegetation is more or less dying out.

MR. ROACH: It is true that in several places where we took our samples the vegetation had the appearance of dying out, but in many cases it was fresh and green, with no dead material on it at all. My reference to the fact that in my opinion it was plants instead of decaying vegetation was due entirely to the biochemical oxygen demand tests, which read practically the same in the open lake as they did in the vegetated areas. The biochemical oxygen demand test is applied to determine the amount of oxygen it will take to use up any available organic matter in the water. Of course there might be some other factor there that we have not considered.

MR. CHARLES O. HAYFORD: One morning when I went down to one of our largemouth bass ponds in which there were about twenty thousand fish it seemed as if every one of them had his nose out of the water. An oxygen test showed a content of six-tenths of one part per million. That was brought about largely by a rapid decomposition of the organic matters in the water, using up the oxygen. I am wondering if we haven't something to worry about in a great many of our shallow lakes where we have such dense growths of vegetation. We had another instance of the kind last year, but just about the time the fish came up to the surface we got a wind and wave action which immediately corrected it. We have been pretty careful since then to keep the vegetation under control.

MR. MARKUS: Out on the west coast in tidal pools containing perhaps not more than ten gallons of water and with nothing in them but vegetation, the oxygen analysis ran the same as it did in those similar to the ones demonstrated here on this lake. During the day the oxygen content was higher, and at five o'clock in the morning it was negative. The only thing that was present in these small idle pools was vegetation.

DR. EMMELINE MOORE: May we have information on the record with regard to the contrivances that have been mentioned for cutting weeds? Are they on the market? What are these weed cutters?

MR. WICKLIFF: As I recall it, the outfit was purchased at Silver Lake, Wisconsin, at a cost of about $600.

MR. ROACH: It is a weed cutter made by C. L. Hockney & Sons, of Silver Lake, Wisconsin.

DR. EMMELINE MOORE: I think Mr. Hayford spoke of one yesterday; may we have some information about the one he uses?

MR. CHARLES O. HAYFORD: Ours is the Atkins weed saw, which we use in our shallow ponds. The Atkins weed saw is made by E. C. Atkins & Company, 402 South Illinois Street, Indianapolis, Indiana. In Mohawk Lake, which is an artificial lake three miles long, they cut the weeds off and pile them up on a raft, but that is rather difficult to manipulate; you have to keep going ashore all the time. I think Dr. Embody was telling me the Germans have a mowing machine which works on the water just as a mowing machine would in the fields.

MR. WICKLIFF: I may add that this is an aquatic mowing machine, that may be modified into a rake or a skimmer.

MR. LANGLOIS: There is still another type of weed saw than the one referred to by Mr. Hayford. It is called the Zeimsen weed saw, and it is sold only by Aschret Brothers of La Canada, California.

MR. MCGONIGLE: Has consideration been given to chemical control rather than mechanical?

MR. WICKLIFF: In fish ponds chemical control is not so much of a problem, but it is different where you have a rather large body of water choked with submerged and floating vegetation, particularly where you have an abundance of fish that may be killed by chemicals when the water temperature is at its height. We have water temperatures of over ninety degrees, and the application of chemicals may cause the death of the fish. Of course you might say the fish may die anyhow where you have an excess growth of submerged vegetation with the duckweed on top. But if chemical treatment could be applied without too great a cost or mortality of fish life it would certainly be well worth trying.

# FRY PRODUCTION FROM EYED-EGG PLANTING

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Eyed-egg planting may be defined as the placing or planting, in suitable gravel beds of streams or rivers, of salmon or trout eggs which have reached that stage of development when the eye of the embryo is quite conspicuous. At this stage the eggs can withstand considerable handling and movement and but a short period of further incubation is required to produce hatch.

A description of the egg planting method, as it has been practiced in British Columbia for a number of years, has already been given to the Society by Harrison (1923) but it may here be reiterated that its chief merit lies in the ease with which the eggs can be transported over long distances in comparison with fry or larger fish, although some authorities claim further that not only is the hatch greater among planted eggs than in hatchery troughs but the fry are stronger and more virile. There can be no question but that shipments of large quantities of eggs can be made more readily, more cheaply, and with much less loss than the transfer of large numbers of fry but upon the points of greater survival and virility decision may wisely be reserved until the arguments have been confirmed.

Experiments have been conducted on small scale at various salmon hatcheries in British Columbia of egg planting in different types of gravel bed (Harrison, 1923) and it is readily seen that the results have been extremely satisfactory. Subsequent tests have been equally as successful. While previous experiments have dealt generally with only a small number of eggs, 500-1,000, a test was made at Cultus lake in the spring of 1934, in cooperation with the Fish Culture Branch of the Department of Fisheries, wherein approximately 50,000 eyed eggs were used. A suitable section of a small stream adjacent to the Cultus lake hatchery was prepared with washed, screened gravel and on February 23, 50,700 eyed eggs from the general Cultus lake egg collection were planted in the regular manner by means of the Harrison planting box.

Downstream from the planted area a wooden tank was so constructed that the fry, upon emergence from the gravel, would drift down into it and be counted. The first fry appeared in the tank April 29 in small numbers until May 2 when the first count was made, 68 days after planting. A list of the daily counts made follows:

| | | | | | |
|---|---|---|---|---|---|
| May 2 | — | 1178 | 8 | — | 2819 |
| 3 | — | 2120 | 9 | — | 1760 |
| 4 | — | 1272 | 10 | — | 885 |
| 5 | — | 9400 | 11 | — | 1265 |
| 7 | — | 16500 | 12 | — | 2056 |

| | | | | |
|---|---|---|---|---|
| May | 14 — 2692 | | 23 — | 46 |
| | 15 — 829 | | 25 — | 68 |
| | 16 — 360 | | 26 — | 32 |
| | 17 — 904 | | 28 — | 41 |
| | 18 — 27 | | 29 — | 9 |
| | 19 — 217 | | 31 — | 5 |
| | 21 — 105 | June | 1- 4 — | 41 |
| | 22 — 48 | | 5-11 — | 12 |

a total of 44,691 or 88 per cent of the total eggs planted.

The efficiency of eyed egg planting, as far as fry production is concerned, is thus generally indicated but it is necessary to point out that this planting was made in a protected area with due provision made against scouring of the gravel by freshet. In ordinary practice it has been found that the success of certain planting efforts has been seriously vitiated by freshets tearing up and scouring out stream beds where eggs have been planted. To achieve the greatest degree of success such natural disturbance of the stream bed should be guarded against or the eggs placed in locations where control of the water supply is possible. The use of wooden troughs in protected areas, filled with gravel and with a small current of water passing through, has been advocated by some authorities.

For similar reasons steps should be taken to guard against depredation by predatory fishes at the time of emergence of the fry. If the transportation and planting of eggs is of any value whatsoever, subsequent care and protection of planting beds and of emerging fry should be worthy of attention. In the past, perhaps too little importance has been attached to these phases and the eggs and fry have been left to the mercy of water conditions and predatory fishes with consequent serious, yet avoidable, loss.

It might here be pointed out that observation of the planted area at the time of emergence of the fry showed that principally after dark, between dusk and dawn, did the young fry emerge from the gravel bed. At that time of day when they would be least sought and captured by their many enemies, the young fry left their protected gravel bed and accustomed themselves to their new environment. The difference between this natural habit and that practiced in ordinary hatchery-fry liberation, normally conducted during day-light, is noteworthy.

So far, attention has been directed to planting of eggs when in the eyed stage. Consideration is, however, being given to the planting of "green" eggs, that is, eggs merely fertilized and hardened. Tests on a small scale have been carried out by hatchery officers with marked success, the results closely approximating those obtained in eyed egg planting tests, and it is proposed to make a test during the fall of 1934 with "green" eggs at Cultus lake, similar to that reported above for eyed.

The utilization of "green" egg planting is limited by reason of the shorter time during which eggs may be handled and transported. At present, it is the practice to confine the movement of such eggs to the first 48 hours as thereafter they are considered to have entered a very delicate phase of development. Furthermore the effects of extended transportation during this early 48 hour period have not been thoroughly tested and at the moment the method is confined to plantings in the area where spawned. In the latter situations it is claimed that costs of hatchery operation are avoided and that a greater output of eggs is achieved. Where late fall freshets are found to occur, however, the planting in early fall in stream beds is fraught with danger unless due protection is provided. It is deemed highly probable that the practice of planting "green" eggs may find an important place in the ultimate scheme of restoration, by artificial propagational measures, of depleted salmon areas.

It should not be inferred that egg planting is confined to sockeye salmon. It is equally applicable to the other four species and in some of these, at least, may prove more successful than with sockeye.

## Summary

An experiment in planting 50,700 eyed sockeye eggs is reported upon from which a total of 44,691 free-swimming fry, representing 88 per cent of the eggs planted, were recovered. This test confirms many others made on much smaller scale and indicates the success which may be achieved by this means of propagation, if due provision for protecting the planting areas from freshets and predatory fishes is made. It was observed that emergence of fry from the gravel bed occurred after dark.

The chief merits of egg planting are the ease and economy of transportation over long distances, whether for the purpose of restocking new or depleted salmon areas or for salvaging and spreading out eggs otherwise deposited by spawning fish in overcrowded, confined gravel beds.

# THE WEATHER MAN AND COASTAL FISHERIES

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## Introduction

Present day meteorology, organized as it is upon a world-wide basis, is called upon for information in many fields of economic endeavor. On this continent, we are dependent upon the meteorologist for a daily forecast of the weather. On the coast we look to the weather man for ample warning of approaching storms of destructive intensity. During periods of drought, agriculturists and foresters look to the weather man with the greatest concern, while stock market quotations undergo rapid fluctuations as the chances for a good grain crop are discounted by the latest forecast. Of late years, oceanic shipping has been greatly interested in attempts for forecast (from an analysis of pressure distribution over the ocean) the number of icebergs that will reach the shipping lanes in the vicinity of the Grand Banks in any given season (Smith, 1926).

Weather forecasts are of interest to the fisheries at the present time in various lines of endeavor. In the cured fish business, it is of importance to know when the fish should be placed on the flakes to dry in order to obtain a good cure. Satisfactory smoking of fish is dependent upon the humidity of the air. The shipper of fresh frozen fish is directly interested in the state of the weather which will indicate the proper time for shipping. Aside from all this there is reason for supposing that at some future time, predictions of weather may play an important role in forecasting the nature of the fisheries. Here is another field for the weather man.

## Oceanography, Meteorology, and the Fisheries

Oceanography (the science of the sea) and meteorology (the science of the weather) are closely interrelated. Brooks (p. 456, 1932) makes the following observations:

> "All the oceans are overlain by the atmosphere. Every change in wind direction or velocity, in air temperature, in absolute humidity, in cloudiness, every shower, disturbs the water surface or changes its temperature or salinity to some degree. And conversely, every change in roughness, temperature or salinity of the ocean surface affects the atmosphere. Nearly three-quarters of the atmosphere is underlain by ocean."

Oceanographic investigations have shown the importance of the physical and chemical nature of oceanic waters to the life contained therein. Fluctuations in the fisheries are, to a large extent, based on fluctuations in environmental conditions. Huntsman (p. 530, 1932) makes the following statement:

"There is as yet very little knowledge of these fluctuations (fishery) themselves, which are so vitally important to man: their adequate explanation will come only as a result of long-continued and extensive investigations of the changes occurring in the sea—so many physical factors exercising, either directly or indirectly, a controlling influence on the abundance of each particular species of fish in each region."

It is reasonable to suppose, however, that because of the close interrelation between the sea and atmosphere, variations in atmospheric conditions play an important role in determining fluctuations in environmental conditions in the sea, and that at some future date, meteorological forecasts will be indicative of environmental conditions and hence of direct importance to the fisheries. That such a supposition is warranted, may be indicated by the relation between atmospheric pressure gradients over the Atlantic Ocean, environmental conditions of waters of the south coast of Nova Scotia, and the coastal fisheries for cod and haddock.

## Atmospheric Pressure Gradients and Conditions in the Sea

It is generally recognized that steep pressure gradients in the atmosphere are of considerable importance to dynamic conditions in the sea. The effect of atmospheric pressure on the level of the sea is clearly expressed by Marmer (p. 149, 1926) as follows:

"Making use of weather records and the data derived from automatic tide gauges, it is possible to work out, for say any given port, a table which will show the change in the time and height of high or low water due to winds of various strengths and directions. But in doing this we would find that another element of the weather was making itself felt, and that is the barometric pressure. It is easy to see that this should be so, for if we assume the atmospheric pressure over the sea as constant, the water in any given harbour may be regarded as constituting a huge inverted water barometer. When the barometric pressure in the harbour rises the water will be depressed, while with a falling barometer the water will rise. Since mercury is about thirteen times as heavy as water, it follows from the above that a change in barometric pressure of one inch should be accompanied by a change in the level of the water of a little more than a foot.

"As a matter of fact, the barometric pressure over the sea is not constant; hence, the level of the water in a harbour does not vary simply as the local barometric pressure, but rather as the pressure gradient, which defines the relation of the barometric pressure in the harbour to that of the open sea in its vicinity. In connection with the determination of mean sea level considerable study has been given to the problem of the exact relationship between changes in barometric pressure and sea level, but here we must content ourselves with the statement that, in general, it has been found that the water in a harbour behaves approximately as an inverted water barometer, falling when the barometer rises and rising when the barometer falls."

It is thus seen that atmospheric pressure is of importance in determining the topography of the sea surface. The topography of the sea surface is indicative of the movements taking place, as the water would tend to move so as to make the surface of the sea level. It therefore follows that atmospheric pressure gradients must be of considerable importance to water movements in the sea. Such importance is probably best indicated by the observations and calculations of Knudsen (see Krümmel, 2, pp. 517-519, 1911) in dealing with the flow of water between the North Sea and the Baltic. From considerations of the atmospheric pressure gradient, Knudsen derived a formula for the calculation of the strength and direction of the current, and his calculated results agreed well with the observed currents. Dawson's observations (Dawson, p. 41, 1920) are of particular interest to Canadian Atlantic waters:

> "The current is found to run more strongly before a heavy wind comes on, and this change is so noticeable that fishermen when anchored in their boats, take it as an indication of an approach of heavy weather. This is found to occur on the coasts of Newfoundland, and also in the Gulf of St. Lawrence on the north shore and in the bays and straits on the south-west side. There is also some evidence of its occurrence in the Bay of Fundy.
>
> "According to this wide-spread testimony, a change in the behaviour of the current is noticeable for about twelve hours before a storm comes on. In most localities, the current sets more strongly towards the direction from which the wind is about to come; although there are other localities where the reverse of this behaviour may occur. Where the currents are weak and variable, the set may become continuous for twelve or eighteen hours before the wind begins. Where the currents are tidal with definite ebb and flood directions, the flow towards the coming wind will be much stronger than usual, and also longer than the ordinary tidal period; and in the opposite direction it will be checked or retarded. These effects are much more marked before north-east or south-east gales than before heavy winds from a westerly direction, as this is the usual direction of the prevailing winds.
>
> "These statements of the fishermen are confirmed by observations obtained by the Tidal Survey, and their main feature is the fact of the current setting 'into the wind' as they express it; and for this it is difficult to give a satisfactory explanation without more extended investigation. But the set of the current towards the point from which a wind is about to come, is in accord with the universal testimony of the fishermen throughout these regions. Of all signs of bad weather, it is the one which they appear to find the most trustworthy."

In the light of present day knowledge of atmospheric conditions over the sea, Dawson's observations may be interpreted. Strong winds accompany steep pressure gradients in the atmosphere, associated in particular, with "lows" or "highs." If, at a given point of observation on the coast, the barometric pressure is higher than that of the open sea, the water level at the point of observation is depressed in

relation to that of the open sea. Consequently, the tendency is for the current to set from the higher water level to the lower (actually the movement would tend to be clockwise around an elevation of the sea's surface, and anticlockwise around a depression of the sea's surface). Air movements, however, are from the area of higher pressure to the area of lower pressure (actually clockwise around a high, and anticlockwise around a low). Hence, the water movements set up before a storm arrives are "into the wind." The phenomenon is thus due to the action of the atmospheric pressure gradient causing water movements which may be detected in an area before the centre of the storm arrives in the vicinity.

In an area of highly stratified waters, such water movements following from atmospheric pressure gradients may have a pronounced effect on a body of water. It is readily appreciated that a surface flow towards a coast must be compensated for by a flow at some deeper level away from the coast. Consequently the highly stratified waters may be replaced in time by surface waters (if the surface flow is towards the coast), or bottom waters (if the surface flow is away from the coast).

## Variations in Bottom Water Conditions on the South Coast of Nova Scotia

The waters of the south coast of Nova Scotia are highly stratified during the summer, both as to temperature and salinity (Hachey, 1934a). The surface waters are warm (as high as 20.0° C.) and of low salinity (as low as 30.00‰), as compared with inshore bottom waters with temperatures as low as 1.0° C. and salinities as high as 33.50‰.

Variations in the nature of the coastal waters may be followed quite readily in Halifax harbour. Weekly observations of temperature and salinity have been made in the harbour over a period of years. Rapid, large and seemingly erratic changes in temperature and salinity have been noted. These large variations in temperature and salinity are found to be related to the distribution of atmospheric pressure over the neighboring ocean (Hachey, 1934b) and are the result of relative water movements in the water layers.

In Figure 1, these bottom temperatures and salinities are plotted for the period August to October inclusive for 1933. Pressure distribution over the neighboring ocean on September 4th, and September 18th is indicated in Figures 2 and 3 respectively. It is obvious from these figures that the high temperatures (13.7° C.) and low salinities (30.24‰) of the bottom waters on September 4th are associated with a high pressure area in the vicinity of the Nova Scotia coast, and a low pressure area of several days' duration over southern waters. Again, on September 14th the bottom water temperature is 2.5° C., while the salinity is 32.25‰, and this condition is associated with a low pressure area in the vicinity of the Nova

Scotia coast, and a high pressure area over the mid-Atlantic. The high temperatures and low salinities of the bottom waters for September 4th can only be of surface origin. Consequently it would seem that a high pressure area in the vicinity of the coast coincident with a low pressure area over the open ocean is responsible for a "piling"

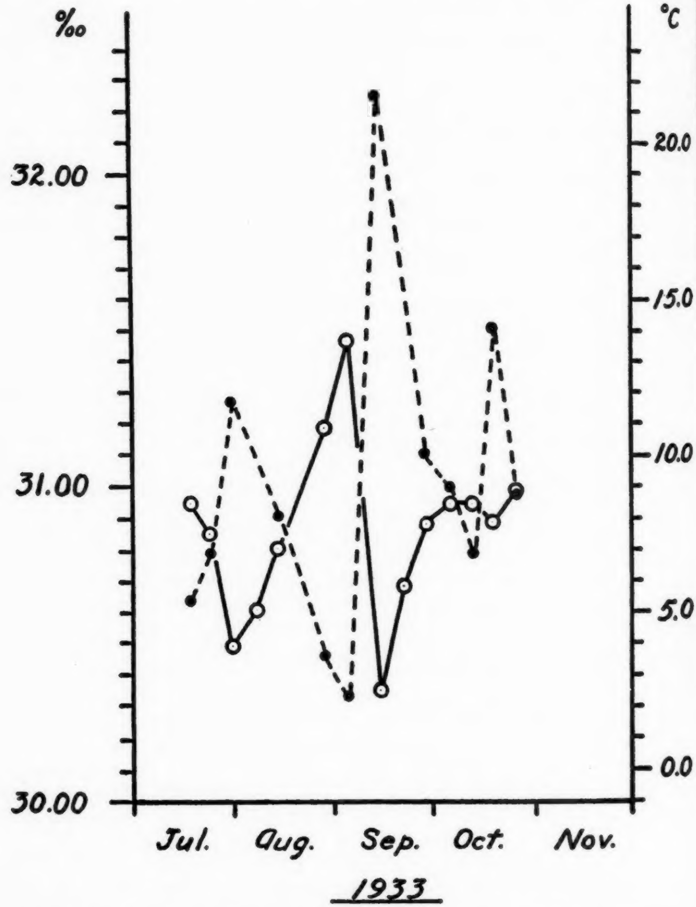


FIGURE 1. Bottom salinities (dotted line) and temperatures (continuous line) in Halifax harbour.

of surface waters near the coast with a resulting displacement of the bottom waters of low temperature and high salinity. When the pressure gradient in the atmosphere is reversed (a low pressure area in the vicinity of the coast coincident with a high pressure area over the open ocean) the surface waters are driven from the coast with resulting "in-rush" of cold water of high salinity on the bottom.

## The Effect on Inshore Ground Fisheries

The relation of the cod and haddock to water temperatures has, of late, been given considerable attention. Vladykov (1930) has shown that high temperatures stop haddock fishing, while McKenzie (1934) indicates that most of the cod are caught in water of a temperature between 0.5° C. and 7.0° C. Le Danois (p. 38, 1932) claims that at temperatures between 3.0° C. to 5.0° C. cod are very abundant, and that at temperatures between 5.0° C. and 7.0° C. haddock are very abundant. However, it is admitted that sharp upward changes in the temperature of the water will cause the cod and haddock fishery to temporarily disappear. Whether the fish actually move off the ground, or whether they are not inclined to touch the bait, at times

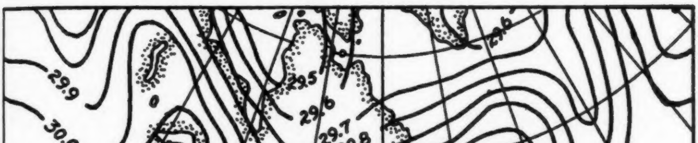


FIGURE 2. Weather map of North Atlantic Ocean, September 4th, 1933.

of higher water temperatures, does not seem to have been satisfactorily determined as yet. One of the main features of the inshore fishery of the south coast of Nova Scotia is the erratic nature of the fishery, and to a certain extent (in certain areas at least) this condition may be correlated with sharp changes in the temperature of the bottom waters. As these sharp changes in temperature of the bottom waters are correlated with changes in the direction of the atmospheric pressure gradient, the interrelation between meteorology and fisheries in certain regions becomes evident.

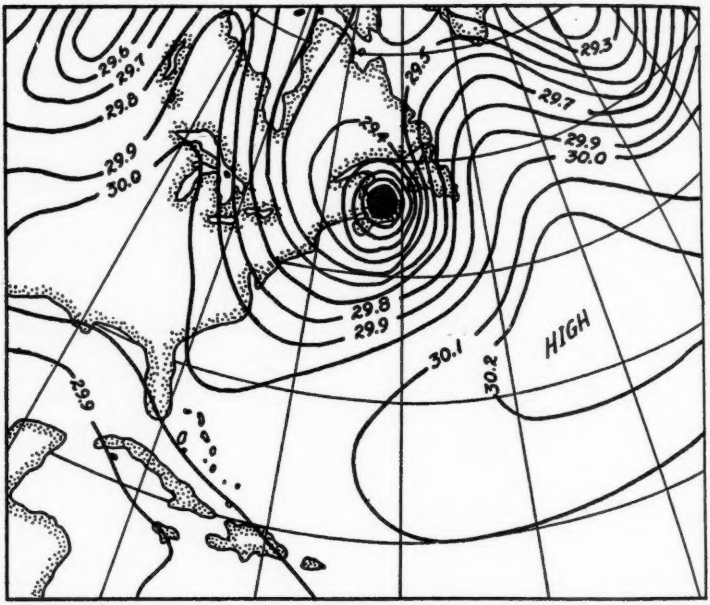


FIGURE 3. Weather map of North Atlantic Ocean, September 18th, 1933.

## SUMMARY

The interrelation between meteorology, oceanography, and the economic aspect of the fisheries has been touched upon, in order to indicate the probable importance of marine meteorology to the forecasting of the nature of the fisheries in a chosen area. It would seem that conditions in the waters of the south coast of Nova Scotia are linked up with the conditions in the atmosphere over the neighboring ocean. These changing conditions in the water are of practical importance to the prosecution of the fishery for cod and haddock. May

we not then look forward to the time when the weather man will form an important adjunct to methods of forecasting the nature of the fishery in a given area?

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# FISH PARASITES AND THEIR IMPORTANCE

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Since fish are not only definitive hosts for a very large number of species of round and flat worms, but are the intermediate hosts for many more (the definitive hosts of which are mammals, birds, amphibians and other fish) the study of fish parasitism is of considerable importance, not only to pisculturists but to all interested in the conservation of wild life and to health authorities.

When considering the effects of parasites on animals the following two facts must be remembered.

During the adult stage the helminths' main function is to reproduce; this stage may last several years, during which the daily egg production is measurable in thousands, tens or even hundreds of thousands: therefore, the host must not be seriously harmed as a mature helminth cannot, in nature, re-establish itself in another host. There are, of course, very many cases where man, by upsetting the balance of nature, either has caused such severe cases of parasitism that the host is damaged or the egg-laying capacity of the worms decreased, or has introduced worms into new hosts, frequently severely damaging them.

The second fact is almost the converse—that since for the completion of the parasite's life cycle the first and/or second intermediate host may have to be ingested by the next host, damage to the health of the *intermediate* host may make it more easily caught. This frequently occurs—especially in the larval stage of tapeworms, although many exceptions to this rule exist.

The importance of helminth parasites to fish was stressed by Linton speaking at the World's Fisheries Congress forty-one years ago when he stated that "of all animals . . . the class of fishes takes the lead, not only for the variety of forms and the number of individuals harbored, but also for the frequency of individual cases of parasitism." Speaking some years later, he reports taking 7,932 cysts of the tapeworm, *Otobothrium crenacolle* (whose definitive host is a shark), from a common butterfish, *Poronotus triacanthus,* and counting 74 and 81 trematode cysts from the cornea of the eyes of a tautog, while from a young sucker (*Catostomus arderis*)—which weighed 9.1 grams—he collected 3 *Ligula catostomo* which weighed 27.5 per cent of the weight of the host. Naturally such comparatively large parasites are not only a direct drain on the host but mechanically may press on vital organs. Ward has shown that over eighty per cent of fresh water fish are parasitized and that they also harbor many different species. Bangham's report on the parasites of bass last year confirms their high degree of parasitism. Nichol, working on both the east and west coasts of Scotland notes that 80 per cent of the sea fish there are

parasitized—nematodes occurring in 76 per cent, trematodes in 70 per cent and cestodes in 46 per cent. Only 4 per cent of the nematodes occur in the alimentary tract—a point which is of considerable aesthetic importance in edible fish.

In the higher animals parasites seldom occur in the testicles or ovaries, but in fish they more frequently are the cause of sterilization—a point of importance to conservation workers.

Owing to the small number of nematodes requiring a single host which are found in the intestinal tract of fish, overcrowding of fish may be expected to have less serious results than man has created under agricultural conditions. But, if man, in hatcheries or by stocking, in addition to crowding fish, also concentrates the intermediate host, or definitive host of a parasite for which fishes are the intermediate hosts, most serious results can be obtained in a very few weeks at certain times of the year.

Up to the present, those parasites for which fish are the intermediate hosts and man or domestic animals the definitive hosts, have been considered of greater economic importance than those parasites for which fish are the definitive hosts. Accordingly much more work has been done in elucidating their life histories and although much is already known, there are still many gaps in our knowledge.

In North America what is known as the *Broad Fish Tapeworm* (*Diphyllobothrium latum*), has received most consideration and publicity. In addition to man, in whom the incidence seems to be increasing, it is known to occur in dogs and occasionally cats, and in over a score of wild fish-eating mammals. There is some controversy as to the amount of harm this worm can do to man; but there is no doubt that if the fish-eating public receive the impression that fish can be a dangerous food—although, when properly cooked, it is perfectly safe parasitologically—the harm done to those interested in the fish trade will be immense.

In North America the chief foci of infection are around the Great Lakes; in Europe around the Baltic, in Switzerland and around the Delta of the Danube; and it occurs in Ireland. It is also reported from a few districts in Asia and Africa.

In North America, *D. latum* was first reported in the second half of the nineteenth century in Europeans; it has, therefore, been assumed that it is a comparatively recent importation, but it must be remembered that, for centuries there has been considerable immigration from north Europe to North America. *D. latum* has been reported from bears in Alaska and Yellowstone Park, but in eastern Canada it has not yet been proved that fish are infected. Data on this are at present being collected, but even if the fish of the Province of Quebec are not already infected, there is considerable danger that they will become so, since *Diaptomus oregonensis*, one of the first intermediate hosts, is common in some waters, and the known fish intermediate hosts also are plentiful.

The distribution of *D. latum* is only limited by the distribution of the intermediate hosts. After the eggs leave the host in the faeces, should the latter reach water, larvae hatch from the eggs in from twelve days to ten or eleven weeks, and die after a few hours or a few days free swimming, unless swallowed by a suitable crustacean. In North America, *Cyclops brevispinosus, C. prosinus* and *Diaptomus oregonensis* have been found to be capable of being first intermediate hosts. After being swallowed by a suitable crustacean, the larva bores through the intestine into the body cavity where further development takes place. This stage needs 2 or 3 weeks, after which, if any suitable fish eats the crustacean, the *D. latum* larvae can bore into its muscles and develop into the stage which is infective to mammals.

A large number of fish are known to be capable of acting as the final intermediate hosts: In North America, the pike, northern pike or jackfish, *Esox lucius;* the wall-eyed pike, pickerel or doré, *Stizostedion vitreum;* the sand pike, *Cynoperca canadensis;* the burbot, *Lota maculosa;* and the perch, *Perca flavescens.*

In addition to pike, perch and burbot, in Europe, trout, grayling, miller's thumb and white fish, in Japan, Pacific salmon, and in Africa, barbel, have been implicated.

The infective stage is usually situated in the musculature around the body cavity, but may be found in the liver, connective tissue or free in the body cavity. Finally, to complete the life cycle, the infective fish has to be eaten by man or a carnivorous animal in which maturity is reached by the tapeworm in four to six weeks. The adult stage may live for several years, and the average egg production has been variously estimated at 800,000 to ten times that number daily; therefore, each worm which reaches maturity is capable of producing billions of eggs.

There are several points of economic importance in the life of *D. latum* about which there is insufficient knowledge; especially those points which concern the infective stage. For instance, it is known that a temperature of —11° C. for 24 hours is lethal to them in dead fish, even when a dozen are packed tightly together and the lowest temperature can only reach the centre fish for a short time, but —3° C. in otherwise the same conditions is not lethal. Unfortunately such severe freezing would present difficulties in practice. It may be found, however, that a slightly longer time at a higher temperature, or variations in temperature, may make fish from infected districts safe for raw consumption or proof against insufficient cooking; the time factor may be expected to vary with the size of the fish. Chemical methods of making raw fish safe should also be studied in addition to temperature and storage methods. In live fish, it has been observed by Nicholson, that most of the larvae, which can only be acquired in the warmer months, are dead by the following spring, and that those which do survive until then are less likely to be able to establish themselves in a mammalian host. In August 60 per cent may become mature, but in spring under half that number can be established. It has also been

observed that large pike are much less heavily infected than medium sized fish, perhaps, owing to increased thickness of the intestinal wall. Wardle has noted that there is considerable variation in the incidence of infection between different species of fish which are the intermediate hosts in the same district. The known fish vectors are fish-eaters and many plankton feeders are not, and therefore, it has been suggested that they may become infected by eating a smaller fish which is carrying a larva, although the latter does not appear to have any suitable structure for boring through a second fish's intestinal wall.

The Institute of Parasitology is making a survey of the animal parasites which occur in Canada, especially in those animals which are of economic importance. So far, the amount of material which we have been able to examine is small compared to the size of the country, but it does appear that a related fish-carried tapeworm is common in New Quebec and Baffin Island. So far we have only seen adults from one dog—in which case the segments were narrower than those of *D. latum,* but similar eggs have been seen in dog faeces from several posts. Species of this family have also been reported from marine mammals. We have been informed that at the mouth of the Mackenzie River, the natives will not feed certain species of fish in a "green" stage, as they know they will give their dogs worms.

At the end of last century it was shown by Linton that the conservation of birds can react unfavorably on fish life. In Yellowstone Lake the large white pelican, (*Pelecanus erythrorhynchos*) was heavily infected with the tapeworm *Dibothrium cordiceps* for which the Mykiss, *Salmo mykiss,* is the intermediate host. On the west area of the lake there are warm springs which lengthen the period during which the water is warm enough to hatch the eggs passed in the faeces of the pelican. The warm water area is heavily stocked with fish which specially attract the birds as the intermediate stage bores into the flesh of the fish, weakens them, and makes them an easy prey, creating a vicious circle. For this reason for some time the pelicans of Yellowstone Lake were not fully protected; now they are fully protected.

Fish-carried flukes may easily prove to be as important, if not more important, to man and domestic animals in Canada than fish-carried tapeworms. But owing to the difficulties in diagnosis, the adults and the eggs being very small, the damage they cause must frequently be ascribed to other causes.

Their life history in the species for which it is known is as follows: the eggs are passed in the faeces in a developed state, but they do not hatch until the egg is ingested by special species of water snail. In the gut of the snail the egg hatches and the larvae migrates through the lymph spaces to the liver of the snail and, by asexual multiplication, produce tailed larvae or cercaria. These migrate from the liver of the snail into the water and after swimming to a fish, digest themselves either into the skin or into a scale. The life of the cercaria unless it can find a suitable fish on which to encyst is short.

Little is know about the cysts' potential life after the death of the host, but those of *Clonorchis sinensis,* the cause of "Asiatic Liver Fluke Disease" in man, dogs and cats, do appear to be more resistant than most helminths to high temperatures, although efficient cooking is of course, lethal.

Immigrants from eastern Asia, in whose faeces *Clonorchis* eggs have been found, have been excluded from the United States of America as carrying a "contagious and loathsome disease." Nevertheless, it must sometimes have gained access; yet so far, it is not reported as having become established. In North America there are other members of this family, some of which are undoubtedly causing considerable damage, especially to sledge dogs which receive a fresh-water fish diet. So far, man has not been reported as a host of these species, but since these flukes are less specific in their definitive host requirements than most helminths and since they have been reported from a number of other fish-eating animals, it would be most surprising if man is not a potential host. The two most common species are *Opisthorchis pseudofelineus* and *Parametorchis complexus,* the latter in some districts of the Prairie provinces of Canada being very serious. In eastern Canada we have seen Opisthorchid eggs in dog faeces from north of Quebec city, from the Quebec-Ontario border and in Ontario from the mouth of the Moose River.

In addition to cysts of the family Opisthorchidae, fish or crayfish in North America also carry those of the families Heterophyidae, Troglotrematidae, Strigeidae and some Echinostomatidae.

The fluke *Troglotrema salmincola* is of great importance in the northwest of the United States of America since it has been shown to carry the virus of "salmon poisoning" disease to dogs. Simms has shown that there are several points of unusual interest in the disease; principally that only in combination with salmon can the cercaria transmit the disease to dogs, and that one attack confers a solid immunity. This fluke's distribution is wider than the disease, having been reported as far east as Ontario. It is also found in the lynx, coyote and raccoon.

In local cats we have found the Heterophyid fluke, *Toxotrema venustus,* which, in addition to cats and dogs, has been found in Arctic foxes. This family of flukes has an extremely wide range of hosts, including fish-eating birds as well as mammals.

It is probable also that, although the number of species of snails which can act as first intermediate hosts for these families of flukes is limited, the species of fish which can act as second intermediate hosts is much less restricted. For instance, thirty-four species of fish belonging principally to the families Percidae, Gobiidae and Anabantidae are second intermediate hosts for *Clonorchis sinensis* in Eastern Asia. A high percentage of the fish caught at Ste. Anne de Bellevue (black and rock bass, pike, doré and sunfish) carry fluke cysts; in the spring they usually appear degenerate and are surrounded with

pigment granules, presumably having been acquired a considerable time previously. The cysts occur on the tail and fins as well as on the head and body, and the highest number we have found locally is about 500 on a five-inch fish.

Migratory fish can also acquire cysts. We have found them on "Gaspé" salmon and on Arctic char, *Salvelinus alpinus,* caught near the sea.

It is probable that the majority of cysts which are found on fish from rivers and lakes of Quebec are those of flukes whose definitive hosts are birds or even frogs; but even if this is the case, raw fish must be looked upon as a potential source of disease to man and mammals. Cooking removes this danger but in many districts of Canada, where fish serve as dog food, cooking is impracticable. Therefore, it is important to know whether all the cysts would be removed by skinning fish, whether the fish have large or small scales or are thin or thick-skinned, and whether salting, freezing or alternate freezing and thawing fish would be lethal to the cysts—all points on which our knowledge is at present entirely inadequate.

The cercaria of many species of holostome flukes infect the eyes of fish. Over a century ago von Nordmann recorded finding 270 larvae in the lens of an eye of *Cyprinus erythrophthalmus,* 98 larvae from the vitreous humor, and more larvae from other parts of the eye—a total of about 400 larvae were found in one eye.

La Rue and his co-workers have observed that in summer in Douglas Lake, Michigan, over 70 per cent of fish have metacercariae in their eyes; the highest number found there was about 450 *Diplostomums* in the eye of a perch, (*Perca flavescens*). They found that the sucker, *Cotostomum commesonii,* was the fish most commonly infected with *Diplostomum.* Another cercaria was found to infect somewhat fewer fish and was found in much smaller numbers. These two cercaria have to be very numerous in the eyes of grown fish to cause macroscopic lesions. "Pop-eye," one of the causes of which is cercaria, in the eyes of young trout has undoubtedly been the cause of death of hundreds of thousands of fingerling fish, the name of the disease describing the symptoms. Taylor and Baylis have found that a cercaria from the snail *Limnaea stagnalis* of South Wales, establishes itself in the eye very rapidly after entering the host; it has also been found that if a very severe attack is made by the cercaria on a small fish, violent excitement occurs and death rapidly follows. Prevention, not cure, is the only hope for hatcheries with "Pop-eye" and this must consist of breaking the life cycle either by preventing the definitive host—probably a bird—defecating in the water supply or by killing off the first intermediate host—the snail.

Nematodes in the larval stage are also the cause of much damage to fish. Ascarids encysted in the flesh of cod or butter-fish have been and are, frequently the cause of greatly depreciated market values. Most of the larvae occur in the viscera, but some embed themselves

in the flesh where "candling" will reveal some but not all; cooking tends to make those which remain conspicuous. Much prejudice is therefore felt against cod, especially those inshore fish which are most frequently infected, and some fishmongers do not sell cod for this reason, although to man, they are entirely harmless, the definitive hosts of these ascarids being most probably seals or dog fish.

In fresh-water fish, encysted larval nematodes also frequently occur, but none are transmissible to man. Fish—like all aquatic animals—are the definitive hosts for a very large number of helminths of the four classes, trematodes, cestodes, nematodes and acanthocephala. Unfortunately much less is known about the life histories of fish parasites than about those of domesticated animals, and even less is known about the pathological condition they may cause to the hosts. The evidence at present suggests that while in a few cases they may cause serious harm, in others little damage is done and in some cases they may actually be of use to the fish. Ward records having taken 5,000 flukes from a single dog-fish (*Amia*) and notes that larger figures have been recorded. Swales post-mortemed pike (*Esox lucius*) caught locally in spring, in which cestodes were so numerous that the intestines appeared completely blocked, yet the host was in excellent condition. Wardle notes that heavy infections of cestodes do not appear to damage mature animals, but they may provoke malnutrition and nervous disturbances in immature animals, such as fingerling trout or salmon. Cases have also been reported of parasites so numerous that they distended part of the host with harmful pressure on other organs.

The available data seem to indicate that the adult life of some fish parasites, especially cestodes, is shorter than that of helminths parasitizing mammals. For example, Wardle states that in Manitoba, in pike (*Esox lucius*) the tapeworm, *Trioenophorus tricuspidatus*, which is acquired in spring, matures some ten months later and is expelled at the end of spring, dates comparable with those applicable to Europe, where also *Eubothrium crassum* has the same length of mature life but maturity is reached two months later. In temperate or sub-Arctic regions water temperatures vary rapidly with the change of seasons; therefore, the aquatic fauna changes rapidly and the parasite's life history can only be fulfilled at certain seasons.

Fish, unlike most mammals, but not unlike birds, may radically change their feeding habits not only with age but seasonally. Van Cleave and Mueller note that fish are most heavily parasitized at the season when they are most actively feeding. Those species which remain dormant and fast through the winter, lose most of their parasites at that time. Other species, like the pike and pike-perch which continue feeding during winter, tend to retain their parasites through this season.

In mammals age tends to produce a resistance against some nematodes; in fish it is difficult to determine whether this occurs or

whether it is due to the fact that some fish, as they grow older, cease to feed on such foods as small crustaceans which act as intermediate hosts.

In man helminthiasis most frequently occurs in tropical climates. In fish parasitism seems to be as severe in cod caught off the north coast of Quebec as in warmer waters: Arctic char, caught in summer in water which was still ice-cold, were heavily parasitized.

In addition to endo-parasitic flukes, fish are hosts for ecto-parasitic trematodes: they are common not only in sea-water but in fresh water fish. Their life history is usually simple; that is, the eggs pass out of the adults, hatch, and the young flukes attach themselves at once to the host, without spending a part of their life in an intermediate host. Of course, over-crowding of fish produces ideal conditions for these flukes to increase. Their commonest habitat is the gills. No part of the body of fish from head to tail is immune to the attack of parasites, but adult worms are least frequently found in the liver or gall bladder.

Apart from the fact that our knowledge of the biology of helminths of fish is much more limited than our knowledge of helminths of mammals, the habitat of fish and their feeding habits will make control much more difficult, if not impossible in many cases. Herbivores ingest most of their serious parasites *on* the food; fish ingest them *in* the food. In some hatcheries it may be possible to effect some control. In nature, even if it were possible to kill off one species of animal in order to break the life history of the parasite, the loss of that animal as a source of food might easily be more serious than the harm done by the parasite.

It does not seem impossible that parasites may also play a part in upholding the balance of nature between various species of fishes. It has been noted that those fishes which live on other fish are the most heavily parasitized. In mammals, some of the most harmful worms are those of carnivores on which no other animals prey, and it has been suggested that instead of the greater preying on the lesser, the rôles are reversed by the parasites of the larger predatory animals. Ward has noted that migratory fish (the majority of which are predatory) are more heavily parasitized than fresh-water fish, but that the rapacious species of fresh-water fish are almost equally infected.

While it will certainly be impossible for many years, if not forever, to prevent fish being subject to the attack of parasites, it is urgent that means be found to make fish safe for human and dog consumption without the necessity of cooking where this is difficult, and that meanwhile housewives be educated in the necessity of cooking certain fish. Otherwise all fish may acquire an unjustified bad name. Unfortunately housewives are also unable to appreciate that most of the parasites which they may happen to find are harmless to man. It, therefore, is important that fish which is sold should be parasite-

free, otherwise they also may give fish an unjustified bad name.

It is obvious that much work has still to be carried out on the bionomics of these parasites of fish. This cannot be limited to a study of the worms alone but must be extended into the field of fresh-water biology. A knowledge of the feeding habits, habitats and physical requirements of fish will often give invaluable clues to the bionomics of their parasites and suggest means of control. In a country such as this where fish are of such importance, this is a line of investigation which we cannot afford to neglect.

## Summary

Fish are not only the definitive hosts for a large number of worms, but are the intermediate hosts for many more which parasitize mammals, birds, fish and amphibians. It has been shown that frequently over 80 per cent of fish are parasitized.

In North America the broad fish tapeworm which parasitizes man and many wild animals and whose first intermediate host is a crustacean and second intermediate host a fish, is rapidly becoming of increasing importance. Cooking makes the fish perfectly safe to eat, but other practical precautionary methods remain to be discovered. A related tapeworm is found in the North. In Yellowstone Lake there is a tapeworm of pelicans whose intermediate host is the mykiss and there the conservation of one affords an example of the harm caused to the other.

In North America it is probable that those flukes, for which fish are the final intermediate hosts and snails the first, are of greater importance than tapeworms. Owing to difficulties in diagnosis, however, they are seldom discovered in the final host; they are most certainly a cause of much loss in dogs. Little is known as to what precautions other than cooking should be taken to prevent infecting man or dogs. The larval stage of flukes frequently occurs in the eye of fish and in small fish death may result.

Encysted larval nematodes may be the cause of much financial loss, since although harmless to man, their presence is not tolerated by the housewife.

All aquatic animals are the definitive hosts for numerous parasitic worms. Flukes and tapeworms may occur in enormous numbers; the latter may almost block the intestine of fish. In some cases the mature life of cestodes in fish may be shorter than in mammals. Ecto-parasitic flukes occur frequently in both salt and fresh water. Fish as they grow larger and with the change of seasons change their feeding habits: these reasons may account for some of the changes in their parasitic fauna.

Parasites may play their part in the balance of nature by controlling predatory fish.

Control of fish parasites will not only prove more difficult than those of ruminants because of the element in which they live but because the majority are

ingested *in* and not *on* their food. To enable the life histories of fish parasites to be elucidated, it is important that not only their distribution be carefully mapped out, but that the habits of their hosts be carefully studied.

## Discussion

Mr. Detweiler (Ontario): I would like to ask the last speaker if there are any Ontario records of fish being parasitized by the larva of the broad fish tapeworm?

Dr. Parnell: I cannot say offhand. I have been told that it is east of Toronto, but I should not like to be too definite without looking up the facts.

Mr. Detweiler: I thought they were found as far east as Windsor.

Dr. Parnell: I have been told it is half way between here and Toronto.

Dr. Belding: Would you be willing to tell us if there is any danger to man from any other species of fish tapeworm than that of the broad fish tapeworm, *Diphyllobothrium latum?*

Dr. Parnell: The broad fish tapeworm occurs in man as well as in thirty-two wild fish eating animals. There are about four large families of fish carrying flukes whose first host is the snail. Some have been reported from man as the major host, others from dogs and cats. Its host makes a difference in the size of the fluke, and it is awfully difficult to know whether in given cases it is the same or whether it is not. Man is not a good experimental animal; you cannot feed a cyst to him in order to find out what happens. Uncooked fish is a potential danger, but I think you will find that a large percentage of men who have eaten raw fish in this country were parasitized and did not know it. Most of the symptoms of tapeworm occur after the person knows he has it.

Mr. Langlois: I heard the statement made that a large percentage of the cases of broad fish tapeworm that occur in the United States are more or less directly attributable to the importation of pike perch from Canada. Have you any information on that?

Dr. Parnell: Quite a number of papers have been written on that subject. I imagine the distribution of that tapeworm is wider than already believed. I think where the major amount of fish comes from is where the major amount of infection comes from. On the other hand, those cysts can probably live only a certain time after the intermediate host is killed and therefore carriage comes into the question. But remarkably little work has been done on that subject, and I strongly advocate more.

I may add that at the mouth of the Mackenzie River the natives will not feed what they call "green fish" to their dogs at certain times of the year. I believe it is the same around Lake Winnipeg and Winnipegosis, and perhaps further

south. Drying, and alterations in temperature, are certainly methods of killing most worm parasites.

DR. BELDING: The Atlantic salmon at the time of the spawning has undergone a period of physiological starvation of at least five months' duration. It is frequently infected with tapeworms. In June about 40 per cent of these salmon are infected, and during the spawning time in October about 8 per cent only. Unless there is some unknown case, this would appear to be the only case on record in which a tapeworm parasite disappeared as a result of starvation of the host.

DR. PARNELL: Tapeworms in fish appear to have a shorter mature life than tapeworms in man. The tapeworm in man possibly lives five years or more. In fish it is eight or nine months before they lay eggs, and then two or three months after that they pass out, probably due to the fact that they can only go through the next stage at certain times of the year owing to the necessary intermediate host being plentiful only at certain times of the year.

MR. THADDEUS SURBER: I think you are all familiar with the investigations carried on by Dr. Magath and his associates. One interesting thing which developed as a result of these investigations leads me to the conclusion that the range of that broad tapeworm is restricted to those districts in which people reside who are accustomed to eating uncooked frozen fish. Northern Minnesota, where it is prevalent in large numbers in the fishes of certain lakes in the Ely district, was settled by people from the Baltic regions who were accustomed, as are also the Indians in that district, to eating frozen whitefish during the winter, as well as other fish. With the cooperation of our department, Dr. Magath carried out an investigation to determine whether or not the fish of the Mississippi below the Twin Cities were infested with the larva of this tapeworm. Notwithstanding the fact that one might expect to find such an infestation in an area where the population is so large, no traces were found of the broad tapeworm in that area.

# SIGNIFICANCE OF THE BACTERIAL COUNT AND CHEMICAL TESTS IN DETERMINING THE RELATIVE FRESHNESS OF HADDOCK

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## Introduction

The difficulty in accurately judging the quality of certain types of perishable food products is recognized by all who are concerned with the public health aspects of food distribution. Research by bacteriologists and dairy workers has resulted in the establishment of fairly satisfactory standards of quality for milk and other dairy products. In the meat industry, inspection of trained observers prevents the marketing of unsafe or undesirable meat or animal products.

With the possible exception of oysters, very little has been accomplished in the fishery industries effectively to control the quality of the products sold. One reason for this is the lack of any accurate measure of quality or freshness of the fish. Organoleptic tests, even though made by persons thoroughly familiar with the industry, vary greatly and are at best only a rough indication of the condition of the sample.

Such scientific methods as have been proposed for determining the freshness of most marine products are not very successful and the lack of an easy, accurate test seriously hampers efforts to evaluate different methods of catching, handling and marketing fishery products.

As a step toward the establishment of definite standards of freshness, the present investigation of the conditions existing between the chemical, bacterial and organoleptic condition of comminuted, filleted and eviscerated haddock was undertaken. The investigation is being extended to include other marine fish as rapidly as possible.

## Review of the Literature

There have been numerous attempts to find a standard for measuring the quality of fishery products which would permit accurate comparisons. Anderson (1) has given a very excellent outline of those visible changes in fish which are ordinarily used in judging the quality of the catch. Tillmans and Otto (10) have investigated the occurrence of certain chemical compounds at various stages in the decomposition of fish. Fellers and Clough (3) have studied the occurrence of indol and skatol during the spoilage of salmon.

The bacterial flora responsible for decomposition has been investigated by Hunter (5), Fellers (2), Harrison, Perry and Smith (5), Sanborn (7), Stewart (9), Gross (4) and others. It has been found that although the number of bacteria present in the fish is roughly an index of what may be called its sanitary quality, the numbers found

vary greatly with the method of sampling and also depend upon the treatment the individual fish has received previous to laboratory examination.

Recently Stansby and Lemon (8) have published an electrometric test for determining the relative freshness of haddock. As work with this method progressed, it was realized that knowledge of the actual bacterial counts of the samples would aid in interpreting results and could be used in formulating a standard for the evaluation of fishery products.

## Chemical Examination

The details of the chemical test have been given elsewhere (8), therefore only a brief outline will be included here.

Five grams of the finely ground sample to be tested are shaken with 70 cc. of water for ten minutes and then rinsed with 30 cc. of water into an Erlenmeyer flask and about 0.3 gm. of quinhydrone is added. After shaking for an additional two minutes, the mixture is transferred to a 250 ml. beaker and connection is made with a potentiometer by means of a saturated calomel half cell and a platinum electrode. When the potentiometer reading has become nearly constant, titration of the mixture is begun with 0.0165 normal hydrochloric acid. Successive portions are added and readings are taken until a value of $E = 0.100$ (about pH 6.0) is reached. As soon as equilibrium at that value is obtained, further additions of acid are made until E is equal to 0.200 (about pH 4.3). After rigor mortis of a freshly caught fish passes off, bacterial invasion of the fish flesh occurs.

As the products of these bacteria are mainly basic, the amount of acid necessary to bring the pH to 6.00 is largely a measure of the extent of this invasion. Consequently the number of milliliters of acid added, called the "B" value, rises as bacterial decomposition proceeds. The amount of acid necessary to change the pH from 6.0 to 4.3 is considered a measure of the buffer capacity of the fish protein. During storage, this protein is autolysed by fish and bacterial enzymes and the amount of acid needed to change the pH to 4.3 decreases. Therefore, values of the second step of the titration (A or autolysis values) are in inverse proportion to "B" and to the amount of deterioration that has occurred in the flesh.

## Bacteriological Methods

No standard method for the bacterial examination of fish flesh exists. The majority of previous investigators have concerned themselves chiefly with the classification of the organisms causing fish spoilage and with the question of whether the flesh of freshly caught fish was sterile. For these purposes the surface was usually sterilized chemically or by fire and samples cut aseptically from various depths and localities of the back and belly of the fish. These pieces of flesh

were macerated in saline by shaking with sterile sand or broken glass and proper dilutions were then plated. The above method has the disadvantage that widely divergent counts are obtained from samples taken from different portions of the same fish. Numerous counts are necessary before an average value, representing the fish as a whole, can be obtained. With a commercial fillet the difficulty of obtaining an average value is even greater because of the extreme variations in degree of contamination of the fillet which exist.

## Sampling

In the present investigation, it was found that a more reliable index of the extent of bacterial invasion of the flesh could be obtained in the following manner: The previously eviscerated fish was first washed, dried with a clean towel, filleted, and the fillets skinned with a sterile knife. Commercial fillets were skinned just previous to sampling. The skinned fillet was then ground twice through a sterile food chopper, mixed thoroughly with a sterile spatula, and five gram portions added to two bottles each containing 95 cc. of sterile saline (0.85% salt). The bottles containing the fish and saline were shaken in an automatic shaker for ten minutes. Duplicate plates were made at proper dilutions on agar according to methods of the American Public Health Association for water analysis, and after incubation for three to five days at 25° C. these were counted.

By using the above method, the rise in number of bacteria upon fish or fillets during storage could be followed quite closely. It was, of course, necessary that the fish chosen for any series of experiments be in the same initial condition. Despite precautions, occasional unexpected variations in the number of bacteria found on an individual sample sometimes occurred. Chemical and organoleptic tests both indicated that these variations were due to inequalities in the samples chosen to be tested and not due to errors in making the bacterial examination.

## Classification of Odors

Although no great degree of reliance may be placed on odor as an indication of decomposition, it is interesting to observe at what points different odors appear during storage of fish. Every individual reacts to odors in a different way and it is extremely difficult to convey the sensation or description of odors through writing. In order to simplify classification, the following set of descriptive terms have been used: 1. Fresh or practically no odor whatever; 2, fishy or a faint odor; 3, sweet or a slight odor somewhat resembling a trace of chloroform; 4, slightly stale or somewhat unpleasant odor; 5, stale or rather pronounced unpleasant odor; 6, very stale or decidedly pronounced unpleasant odor; 7, putrid, a repulsive or sickening odor.

In order to obtain spoilage identical with that occurring during commercial storage, the majority of tests were made upon individual eviscerated fish. Seven to nine fish of about the same size and in as nearly as possible the same condition were placed in boxes and kept well iced. At regular intervals an individual fish was taken and tested. Each series lasted until the fish were judged inedible or had reached a condition of advanced spoilage. Eight such series were run and over 56 fish in various stages of decomposition were tested.

A few series were also made upon commercial fillets to compare their spoilage with that of the fish. The fillets comprising any run were kept in cans covered with ice and a separate fillet withdrawn, skinned, and tested each day.

As both the "B" value of the chemical test and the bacterial count rise as storage progresses, they are easy to plot and compare. As the value of "A" decreases during this period, it is somewhat confusing if it is also plotted upon the same graph. Since the maximum value of "A" is approximately 30, with smaller values for less fresh fish, the value of "30-A" can be considered a positive number related directly to the progressive deterioration of the fish. If the value, "30-A" is added to the value "B," a third term is obtained which is always positive and which increases with increasing spoilage.

For an accurate analysis of the changes occurring as the samples age, a consideration of "30-A," ",B" and the bacterial count separately provides the most information. If one is concerned only with a comparison of the chemical test with the bacterial count, the combined value, "B — A + 30," together with the logarithm of the number of bacteria per gram may be plotted against time of storage. A combination of all these values, "B — A + 30" plus logarithm of the bacterial count, is suggested as giving an arbitrary number which

TABLE 1. SUMMARY OF VALUES FOR EVISCERATED HADDOCK

| Logarithm of bacterial count | | Probable length of time since caught | Days in laboratory storage | Organoleptic condition | B—A+30 values |
|---|---|---|---|---|---|
| | | Days | | | |
| 2-3 | Min. | 0 | 0 | Fresh (1) | 13.0 |
| | Max. | 2 | 0 | Fishy (1) | 14.5 |
| 3-4 | Min. | 0 | 0 | Fresh (6) | 7.5 |
| | Max. | 8 | 6 | Sweet (3) | 14.0 |
| | Ave. | 2 | 1 | Fresh (6) | 11.0 |
| 4-5 | Min. | 4 | 0 | Fresh (4) | 8.0 |
| | Max. | 10 | 8 | Sl. stale (1) | 15.5 |
| | Ave. | 5 | 4 | Fresh (4) | 12.5 |
| 5-6 | Min. | 7 | 3 | Fresh (1) | 13.0 |
| | Max. | 15 | 14 | Stale (2) | 22.0 |
| | Ave. | 11 | 9 | Sl. stale (4) | 18.2 |
| 6-7 | Min. | 11 | 8 | Sweet (1) | 17.0 |
| | Max. | 21 | 21 | Putrid (2) | 27.0 |
| | Ave. | 16 | 15 | Stale (4) | 22.7 |
| 7-8 | Min. | 16 | 16 | Stale (1) | 26.5 |
| | Max. | 21 | 21 | Very stale (1) | 36.0 |

is useful as an index of what may be called the "sanitary quality" of fish or fillets.

## Interpretation of Results

The results of spoilage tests on eviscerated haddock kept in ice are summarized in Table 1. The table shows the sharp rise in values which occurs after fish have been caught from seven to eleven days. A bacterial count exceeding the value of 100,000 per gram indicates that deterioration will be rapid. As values of 1,000,000 bacteria per gram and eighteen to twenty-two for B — A + 30 are reached the fish may be considered as no longer in a marketable condition. When kept well iced this occurred eleven to sixteen days after the fish were caught and these would appear to be the limits of time during which unfrozen haddock may be marketed and still be used by the consumer in a fair condition. The maximum length of time which fish were kept before advanced spoilage was reached was twenty-one days. Commercial fillets contained more bacteria than did fillets made in the laboratory from the same lot of fish.

A pronounced or unpleasant odor is a fairly certain indication of advanced decomposition. During the greater part of the time which fish are usually kept the odor is too inaccurate and uncertain to be of much assistance in determining the exact condition of the sample. Both bacterial counts and chemical tests are more delicate and certain than organoleptic standards, but it must be emphasized that no absolute or straight line relationship exists between chemical tests for freshness and the bacterial number. Fresh fish or fillets may be contaminated by handling so that the bacterial count will be very high and yet the chemical tests will indicate that decomposition changes due to this contamination have not had time to occur. During rigor mortis, chemical values decline while the bacteria present usually remain the same or increase slightly in number. Toward the end of a series, the bacterial count may remain the same or even decline a few million per gram, and the chemical tests will indicate a still further advance in decomposition due to combined bacterial and enzymatic causes. The work indicates that there is a general though somewhat uncertain relationship between the freshness of the fish as determined by chemical means and its quality as measured by the bacterial count.

## Conclusion

Bacterial counts and chemical values were obtained of gibbed haddock, haddock fillets, and ground haddock flesh kept in ice for varying periods.

The maximum length of time which whole fish were kept before advanced spoilage occurred was twenty-one days. Ground flesh and commercial fillets spoiled more rapidly than the gutted fish.

The table which has been presented shows the relationship which exists between bacterial counts and chemical tests for freshness when applied to evis-

cerated haddock. It is believed that a combination of these two methods offers a definite advantage in sensitivity and accuracy over the organoleptic tests in determining the degree of freshness of fish. When applied to whole haddock, chemical values of 18 to 22 and bacterial counts of about one million per gram indicate that the fish are no longer in good condition; that they should not be sold as "fresh" fish.

Chemical and bacterial tests for freshness offer a means not only of evaluating different methods of catching and handling fish, but also methods by which definite standards of sanitary quality for fishery products may finally be established.

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## Discussion

Dr. Belding: This is a very interesting paper. From the practical point of view it comes down to how these tests can be utilized by the fish inspector or the public health officer. No one test is absolutely successful in determining whether fish is fresh or stale or fit for food. Even if you have fairly definite tests as indicated, you are up against the practical side, because these cases

have to come to court. The difficulty is the cost of running any chemical, bacteriological or laboratory tests upon as many different specimens as would be necessary for the particular case and a court conviction; and then you are up against the question of taking a bacteriological or chemical analysis into court and being able to convince a judge, or in some rare cases a jury, that any such thing is of value. In only one instance I know of was that issue avoided. I refer to the lobster, where one is able to use the Faradic current as a means of determining the nerve muscle reaction as an index to tissue condition. In that case you could indicate whether the lobster, provided it was not cooked, was fit for food. But I recall that even with that simple test there was a great variation. There is one suggestion that might serve as a control to this excellent work—I happened to note it in that particular instance—I could detect changes in the histological structure of the muscle far earlier than I could any marked increase in the bacteriological count. Possibly you might find that an excellent means of checking your control from the histological standpoint, although it requires very careful histological preparation.

Mr. Griffiths: We have not investigated the histological change of haddock flesh at that period, but it does seem that haddock flesh is quite different from lobster flesh. Lobster will autolize markedly in the first six hours; haddock will take anywhere up to eleven or twelve days before any noticeable change occurs. The chemical test which we have briefly presented is very rapid and can be made rather cheaply. While I do not profess to present a finished research, the chemical test does offer an advantage over visual inspection; we suggest it in addition to visual inspection, because it can be made in thirty minutes or so whereas a bacterial count of the haddock could not be obtained within from three to five days, and by that time your fish has been sold and you cannot do much about it. That is why we have been working on chemical methods in correlation with bacterial count, and we find a fair degree of correlation.

# THE DISSOLVED OXYGEN CONTENT OF FERTILIZED WATERS

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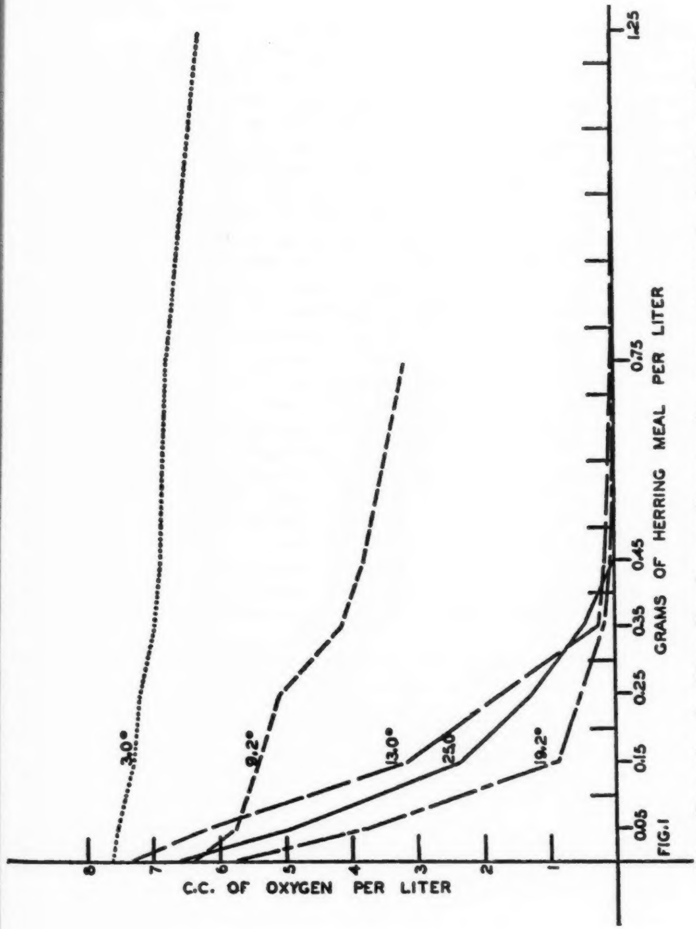
An important characteristic of fertilized waters is the high content of decomposable organic materials. Of these decomposable materials, two categories which are dominant may be roughly distinguished. First, there is the organic material contained in the fertilizer, and second, there is the organic material in the plankton, the growth of which the fertilizing process particularly stimulates. The bacterial decomposition of these organic materials, the fertilizer and the bodies of the dead plankton, materially reduces the dissolved oxygen content, and this reduction of oxygen may become on occasion a decidedly detrimental factor in a fertilizing procedure which otherwise would be quite beneficial. In addition, the respiratory activities of the plankton also utilize oxygen and further tend to lower the supply.

On the other hand, the living plants or phytoplankton, through photosynthesis, produce oxygen and they constitute the principal agency by which the reduction is offset. Diffusion of oxygen into and out of the water (from and into the atmosphere) will increase or decrease the supply, but the process is slow in quiet waters and plays, except when the oxygen tension is extremely low or high, a comparatively minor rôle.

In the course of a series of experiments carried out to ascertain the effect of an organic fertilizer (herring meal) upon the physical and biological conditions in fresh water, considerable data were accumulated in regard to the effect upon the dissolved oxygen content. In Figure 1 are presented certain data to illustrate the action of various amounts of herring meal upon the dissolved oxygen content at several temperatures. The experiment was carried out in darkness and the water was contained in glass-stoppered bottles (250 c.c. capacity). Thus, the maximum depletion for any one concentration of herring meal and at any one temperature was probably realized, since there was no contact with the atmosphere and since, as it has been determined in our experiments, the bacterial action effecting the decay of the fertilizer is greatest in the dark. The time of the experiment was one day, and no chlorophyllaceous plants were present.

The drastic effect of the decomposing fertilizer upon the dissolved oxygen content is well shown. With concentrations of 0.25 grams of herring meal and above, the oxygen content was, for instance, below 2.5 c.c. per litre with temperatures of 13.0,° 19.2° and 25.0° C. Only with temperatures of 3.0° and 9.2° C. was there found any appreciable oxygen content with such amounts of fertilizer.

The above experiment was repeated with the same amounts of




The effect of a fertilizer (herring meal) upon the oxygen content in closed containers at different temperatures. Time, 1 day.

herring meal, but carried out in open flower pots (12 litres capacity). These were exposed to the direct sunshine. As in the previous case no chlorophyll-bearing plants were present. The oxygen content was determined after one, two and seven days.

Under these conditions, although considerably reduced, the dissolved oxygen content was not below 2.5 c.c. per litre with concentrations of herring meal up to 1.25 grams per litre after one day (Figure 2). However, on the second and seventh days the values were below 2.5 c.c. per litre with 0.25 grams, and more, of herring meal per litre. It appears that the contact with the atmosphere and the well-lighted conditions retarded the depletion, but only for a limited time.

In Figure 3a is shown graphically the amount of oxygen found with similar concentrations of herring meal when good plant growths were present (Figure 3b). On the one hand, there was the demand for dissolved oxygen by the decaying organic substances, while on the other, the plants were producing quantities of the gas, particularly in the direct sunlight. After seven days the plant growth was sufficient to maintain, through photosynthesis, an oxygen content of 2.5 c.c. per litre in concentrations of herring meal up to 1.25 grams per litre, but with 6.25 grams per litre, although there were large numbers of plants, the oxygen content was nil even in the immediate surface water. After fourteen and twenty-one days the photosynthetic processes of the plants continued to provide even a better supply of oxygen, except with 6.25 grams of herring meal per litre with which no oxygen could still be demonstrated. It is to be noted that there was no direct correlation between the plant growth and the oxygen content, for the amount of oxygen determined was only that in excess of the biochemical demand of the fertilized water, and was dependent upon the state and stage of the decomposition in each flower pot as well as the number of plants.

In the above instances the decomposing fertilizer was a dominant factor affecting the oxygen supply, and only when a large number of plants were present was an oxygen content of 2.5 c.c. per litre with concentrations of 0.25 grams, or more, of herring meal per litre attained at moderate temperatures (15-25° C.). In an additional experiment only 0.013 gram of herring meal per litre was added to water in an experimental pond (concrete walls) of 36 cubic metres capacity. This amount of meal, as shown above, would have very little effect upon the dissolved oxygen content, even under circumstances favoring the decomposition. Thus, as seen in Figure 4, a direct correlation between the plant growth and the oxygen content was found. During July and August, when the plants were most abundant, a hypersaturation of oxygen occurred. In early September the number of plants became relatively small and with the cessation of photosynthesis and the decay of the plant bodies the dissolved oxygen content declined, not in this instance, however, to a very low value (5.82 c.c. per litre at 12.0° C.). The data illustrate the dual effect of plant growth upon the

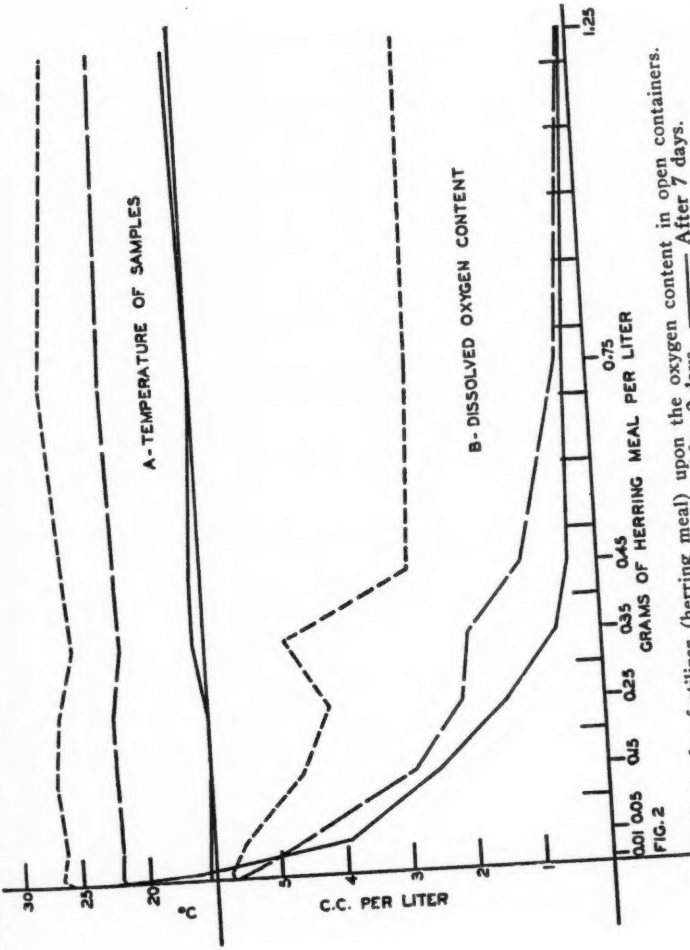



FIG. 2

The effect of a fertilizer (herring meal) upon the oxygen content in open containers. ——— After 7 days. — — — After 2 days. - - - After 1 day.

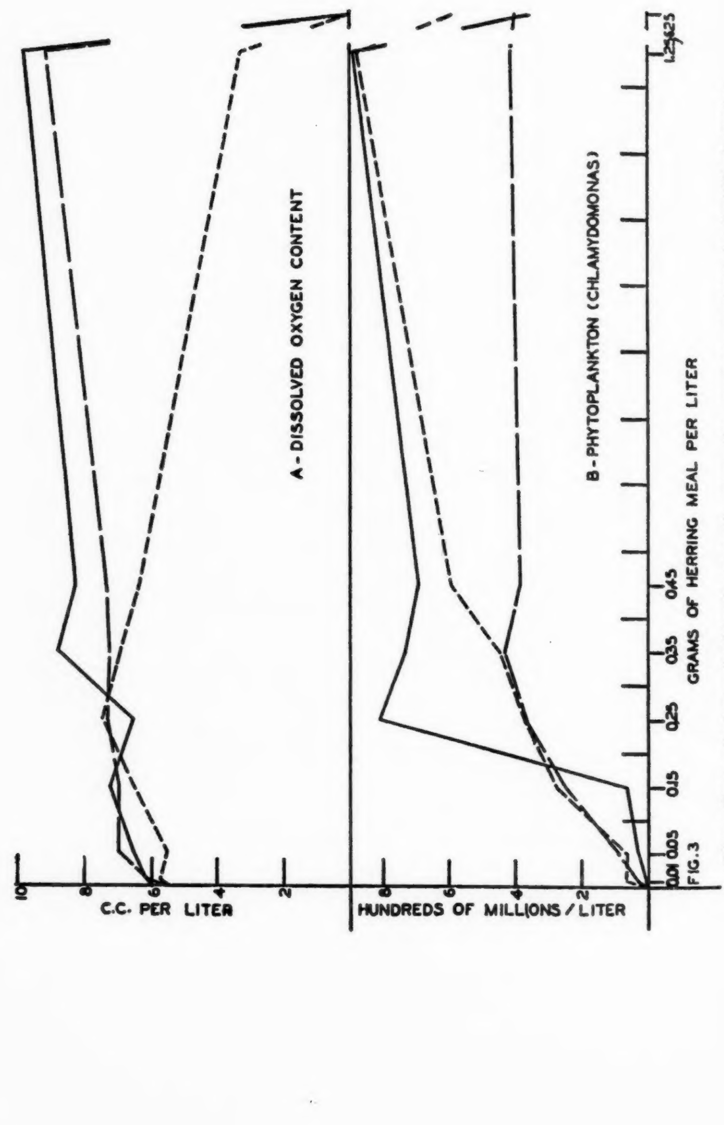



FIG. 3

The effect of phytoplanktonic growth upon the oxygen content in fertilized water.
— — — After 7 days. ——— After 14 days. ——— After 21 days.

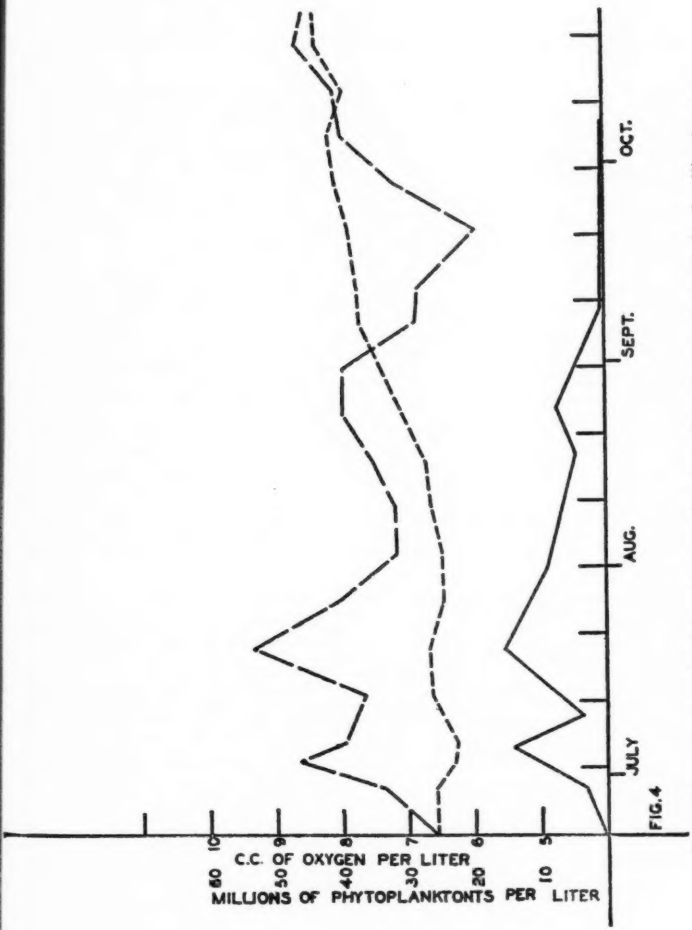



FIG. 4

The effect of phytoplanktonic growth upon the oxygen content in fertilized water. — — — — Oxygen content in unfertilized water (control). —— —— Oxygen content in fertilized water. ——— Phytoplanktonic growth in fertilized water.

dissolved oxygen, first through photosynthesis increasing, then through decomposition of their dead bodies, decreasing it.

Retrospectively it may be seen that the four graphs picture a number of stages from a complete dominance of the decomposing fertilizer over the dissolved oxygen content to one in which the plants play the major rôle.

Studies, such as here presented, on the oxygen conditions in fertilized waters are of decided practical as well as scientific interest, The purpose of fertilizing water is to increase the yield of fish foods and in turn the production of fish. In waters for rearing only fish food (Cladocera, Copepoda, insect larvae, etc.) the oxygen supply may become surprisingly low without seriously jeopardizing the well-being of the aquatic animals or zooplankton. We have observed for instance that *Daphnia pulex* survived in water which had a very low oxygen tension (down to 0.05 c.c. per litre). This does not mean, however, that a prolonged low oxygen tension would not be fatal. Even with the alga, *Chlamydomonas communis,* we have concluded that the anaerobic conditions which occurred with a fertilization of 6.25 grams of herring meal per litre were probably responsible for the smaller growth noted in Figure 3b with this concentration of meal than with lower concentrations. Moreover, Obreshkove (1930) found that the fifth-brood mothers of the cladoceran *Simocephalus exspinosus* demanded only 48.8 per cent of the oxygen consumed by the first-instar young. Thus we may infer that the reproduction of these forms may be affected by very low oxygen contents through limiting the growth of the younger individuals, although the adults might find the habitat more or less suitable.

While in general we may say that the oxygen content may become low without materially affecting the capacity of certain waters for producing fish food, the situation is quite different if the waters to be fertilized contain fish. Of the salmonoids, a group in which we are most interested in the maritime provinces of Canada, Gardner and Leetham (1914) have determined for brown trout that the asphyxial points vary from 0.79 c.c. to 2.4 c.c. of oxygen per litre depending upon the temperature (6.4° to 25° C.). These data are probably representative of the demands of trout and salmon in general, so, for a good margin of safety, the dissolved oxygen values should not fall below 2.5 c.c. to 3.0 c.c. per litre for any appreciable time.

From the results of the above experiments it is seen that there is a limit to the amount of fertilizer that may be added to the water and still maintain this margin of safety demanded by trout and salmon. Further, there is apparently a limit compatible with the best growth of the plant and animal plankton. When a fertilizer is first added to the water, although plants may be present, they are usually not sufficiently abundant to produce much oxygen. A fertilizing of more than 0.25 grams of herring meal, or similar substances, per litre

(1 pound per 400 gallons) is not permissible if a dissolved oxygen supply necessary for fish is to be maintained.

If one waits until the plant growth has established itself, a higher concentration may be possible, but even then a sudden decline in the plant population will depress the oxygen content, perhaps disastrously. Moreover, to fertilize with larger amounts of such materials as herring meal is not an economical procedure, particularly when the body of water to be treated is extensive. In any case decidedly smaller quantities of herring meal (0.01 to 0.05 grams per litre) have proved efficacious for growing fish food, and these concentrations have no drastic action upon the dissolved oxygen content.

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# ALGAE, A FACTOR IN SOME HATCHERY MORTALITIES

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It is not the intention to go into any discussion of Algae, from a botanical, ecological or physiological point-of-view, except as may be necessary to develop the relationship to the mortality induced in one of the smaller Canadian hatcheries, which seems to be referable to the growth and decay of some alga.

This discussion lacks completeness, in that while an alga was observed in the pond supplying the hatchery, samples were not secured for identification as the importance of the plant was not realized at the time of observation, and it was all gone when specimens were sought later. It is hence impossible to state that the alga was a Blue-green or a green, although it was one or the other.

Algae have been recognized as causes of extensive fish mortalities for a long time. It has usually been thought to be due to an indirect action, since the algae do not seem to be toxic in themselves. This indirect action is due to a lowering of oxygen to a lethal level, by the resulting decay of the numerous plant cells. This lowered level of oxygen has been demonstrated several times (Smith, G. M. page 101—also see extensive bibliography in same paper). A more serious effect, also associated with decaying algae, has been described by Prescott (Prescott, G. W., page 77). One of the more common Blue-green algae, *Aphanizomenon flos-aqua,* was found associated with a serious loss of fish, in the presence of ample dissolved oxygen. By experiments, it was shown that the decaying algae produce toxic substances, which apparently caused the death of introduced fish. Analysis revealed the presence of certain protein decomposition products, for example, hydroxylamine, which belongs to a group of chemical substances comprising some of the most poisonous we know, such as the ptomaines, and the alkaloids. These may be referred to as "nitrogenous bases."

Another possible mode of causing loss among fish by algae was discussed by Prescott, in which living algae, by reason of their great numbers, in the absence of sunlight (night-time) could have a sufficiently high oxygen demand to cause dangerous lowering of the dissolved oxygen level. This method is rather unusual, compared to the two previously described methods, of which the first one is considered the more usual type of action, in bringing about extensive losses of fish, especially in lakes. It is however with the formation of poisonous decomposition products by decaying algae that we are interested today.

In 1933, our attention was directed to a case of severe mortality occurring in a small hatchery on Prince Edward Island among the native speckled trout. An analysis of the losses occurring in this hatchery for the preceding three-year period revealed that this loss

occurred annually at approximately the same time in each of the three years. Table 1 gives the analysis for the three years, and also that for the year 1934. A further examination showed that all of the fry carried in the hatchery at this time were also suffering increased loss although not so severely as the native speckled trout. Table 2 gives the corresponding data for the Atlantic Salmon fry.

In preparing these tables, in order to make the periods of each year comparable, each week has been given a number, determined by the date that Saturday occurs. Thus, week 32 is for any week of which the Saturday lies between May 31, and June 6. The mortality data has also been rendered simpler by putting the greatest recorded loss for any week as 1,000, and making all other weekly losses proportional thereto. This eliminated decimal values.

**TABLE 1. MORTALITY OF NATIVE (P. E. I.) SPECKLED TROUT**
**(Loss per Week)**

| (I) | (II) | (III) | (IV) | (V) | (VI) |
|---|---|---|---|---|---|
| | | Year | | | |
| Weeks ending— | Week No. | 1931 | 1932 | 1933 | 1934 |
| April 5-11 | 24 | 12 | 7 | 12 | 2 |
| April 12-18 | 25 | 8 | 4 | 17 | 7 |
| April 19-25 | 26 | 16 | 13 | 12 | 9 |
| April 26-May 2 | 27 | 10 | *21* | *22* | 13 |
| May 3- 9 | 28 | 11 | 4 | *99* | 4 |
| May 10-16 | 29 | 6 | 5 | 9 | 6 |
| May 17-23 | 30 | 4 | 14 | 12 | 8 |
| May 24-30 | 31 | *45* | *36* | 7 | 6 |
| May 31-June 6 | 32 | *24* | 12 | *20* | *35* |
| June 7-13 | 33 | *85* | *380* | *72* | *45* |
| June 14-20 | 34 | *440* | *100* | *540* | *95* |
| June 21-27 | 35 | *620* | *99* | *1,000* | *42* |
| June 28-July 4 | 36 | *45* | *390* | *530* | *32* |
| July 5-11 | 37 | — | *310* | *240* | *23* |
| July 12-18 | 38 | — | — | *55* | *33* |

**TABLE 2. MORTALITY OF ATLANTIC SALMON**
**(Loss per Week)**

| (I) | (II) | (III) | (IV) | (V) | (VI) |
|---|---|---|---|---|---|
| | | Year | | | |
| Weeks ending— | Week No. | 1931 | 1932 | 1933 | 1934 |
| April 5-11 | 24 | 7 | 10 | 5 | 3 |
| April 12-18 | 25 | 9 | 10 | 7 | 4 |
| April 19-25 | 26 | *22* | *40* | 11 | 10 |
| April 26-May 2 | 27 | 5 | *22* | *23* | *36* |
| May 3- 9 | 28 | *21* | *24* | *21* | *29* |
| May 10-16 | 29 | 9 | 15 | *35* | *40* |
| May 17-23 | 30 | 5 | 7 | 15 | 18 |
| May 24-30 | 31 | 11 | 9 | 11 | *36* |
| May 31-June 6 | 32 | *29* | *20* | 10 | *40* |
| June 7-13 | 33 | *90* | *61* | *21* | 16 |
| June 14-20 | 34 | *240* | *78* | *26* | *52* |
| June 21-27 | 35 | *200* | — | *22* | *25* |
| June 28-July 4 | 36 | *20* | — | *74* | *78* |
| July 5-11 | 37 | — | — | *100* | *84* |
| July 12-18 | 38 | — | — | *130* | — |

In these two tables, all losses greater than twenty per week, have been italicized, and a glance will reveal that the losses tended to increase suddenly, particularly those of the speckled trout. The outbreak did not begin in the same week in each of the four years tabulated, neces-

sarily, although the thirty-first and the thirty-third weeks seem to have been the extremes. As already described, the speckled trout usually suffered more severely than other groups (e. g., Atlantic Salmon). This had directed attention to the trout particularly.

These losses were, as has been shown, in no wise confined to any one species, or group, nor were they restricted to any part of the hatchery, but on the contrary, the losses were experienced in all parts, and by all groups, though not with equal severity. This seemed to point to the casuative agent or agents, being of universal distribution in the plant.

There seemed to be three possible conditions existing in the hatchery which would fulfil this requirement: namely, (i) the water, (ii) the food, and (iii) the fish themselves.

Since the food, and the method of feeding were standard, and beef liver, which alone is used, was secured fresh frozen at frequent intervals, it seemed improbable that this would be responsible.

Regarding the fish themselves, a critical stage of development might be reached just at this time, but even so, some other factors would have to operate simultaneously, for such a stage must be passed through by all fish, and a loss as that indicated here does not seem to occur in other hatcheries. It may be that the fish have reached a stage where a "physiological stress" might be experienced, making the fish more susceptible to some other unfavorable influence which might be in existence (a) all the time, or (b) just at this particular stage. This possibility was tested by tabulating the highest and lowest weekly temperatures (Table 3).

TABLE 3. WEEKLY MAXIMUM AND MINIMUM TEMPERATURES (° F.)

| | | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1931 | | 1932 | | 1933 | | 1934 | |
| Week ending— | Week No. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. |
| April 5-11 | 24 | 38 | 32 | 36 | 33 | 36 | 32 | 36 | 32 |
| April 12-18 | 25 | 41 | 33 | 40 | 36 | 38 | 32 | 38 | 34 |
| April 19-25 | 26 | 51 | 41 | 47 | 38 | 44 | 38 | 50 | 38 |
| April 26-May 2 | 27 | 48 | 40 | 49 | 39 | 46 | 40 | 51 | 40 |
| May 3- 9 | 28 | 54 | 41 | 48 | 42 | 54 | 42 | 54 | 42 |
| May 10-16 | 29 | 50 | 44 | 57 | 44 | 52 | 44 | 54 | 42 |
| May 17-23 | 30 | 68 | 45 | 58 | 51 | 56 | 46 | 48 | 42 |
| May 24-30 | 31 | 69 | 52 | 54 | 47 | 57 | 52 | 55 | 48 |
| May 31-June 6 | 32 | 62 | 50 | 60 | 48 | 60 | 50 | 66 | 52 |
| June 7-13 | 33 | 62 | 54 | 65 | 51 | 66 | 58 | 62 | 52 |
| June 14-20 | 34 | 67 | 58 | 64 | 53 | 66 | 58 | 60 | 52 |
| June 21-27 | 35 | 65 | 58 | 65 | 58 | 62 | 53 | 66 | 52 |
| June 28-July 4 | 36 | 70 | 54 | 67 | 60 | 74 | 60 | 70 | 60 |
| July 5-11 | 37 | 70 | 63 | 66 | 60 | 72 | 62 | 71 | 54 |
| July 12-18 | 38 | 68 | 61 | 66 | 60 | 72 | 62 | 74 | 64 |
| July 19-25 | 39 | 75 | 60 | 68 | 61 | 74 | 67 | 78 | 66 |

From this table it can easily be seen by comparison with Tables 1 and 2 that the losses usually begin each year in that week in which the minimum temperature has reached 50° F. This would seem to account, in part if not entirely, for the differing week of onset in each year. In this connection, the year 1932 is very interesting, for it will be observed that the temperature (minimum) reached 51° F. during

the thirtieth week, and corresponding therewith is an increased loss (Table 1) which loss decreased with the drop in temperature for the next week, only to rise again with the rise of temperature. This particularly emphasizes the close relationship of the temperature to these losses. This suggests that the trout might have reached a phase of metabolic transition (M'Gonigle, p. 119) and hence would be probably more susceptible to any unfavorable condition. Such a condition could explain the differences in reaction between the various species.

It is evident, however, that still some other factor must be operating, and it seemed most likely that it would be found in an altered water supply. Accordingly, the water supply was carefully examined, and such an alteration was discovered (Table 4). The springs, and other inflowing waters were examined, and the pond itself, both surface and intermediate layers, and the water actually entering the hatchery.

**TABLE 4.**

| Part Investigated | Data, for the year 1931 (January) | | 1933 (July) | | 1934 (June) | |
|---|---|---|---|---|---|---|
| **TEMPERATURE:** | | | | | | |
| In Hatchery trough—head | 3.2° C. | | 73-68° F.* | | 15.5° C. | |
| In Hatchery trough—foot | ---- | | (23° C.) | | 15.5 | |
| In Pond—surface | ---- | | ---- | | 15.5 | |
| In Pond—bottom | ---- | | ---- | | ---- | |
| In Brook—upper end | ---- | | ---- | | 9.0 | |
| In Brook—lower end | ---- | | ---- | | ---- | |
| In Spring | ---- | | ---- | | 8.0 | |
| **pH:** | | | | | | |
| In Hatchery trough—head | 6.8 | | 9.4 | | 10.0 | |
| In Hatchery trough—foot | ---- | | 9.4 | | 10.0 | |
| In Pond—surface | ---- | | 9.4 | | 10.0 | |
| In Pond—bottom | ---- | | ---- | | 6.8 | |
| In Brook—upper end | ---- | | ---- | | 6.8 | |
| In Brook—lower end | ---- | | ---- | | 10.0 | |
| In Spring | ---- | | ---- | | 6.8 | |
| In House | ---- | | 6.8 | | ---- | |
| | c. c. per L. | Saturation % | c. c. per L. | Saturation % | c. c. per L. | Saturation % |
| **OXYGEN VALUES:** | | | | | | |
| In Hatchery trough—head | 6.5 | 70 | 10.9 | 180 | 8.74 | 125 |
| In Hatchery trough—foot | 6.9 | 74 | 10.1 | 167 | 8.17 | 117 |
| In Pond—surface | ---- | ---- | 8.77 | 145 | 9.46 | 135 |
| In Pond—bottom | ---- | ---- | ---- | ---- | ---- | ---- |
| In Brook—upper end | ---- | ---- | ---- | ---- | 7.32 | 81 |
| In Brook—lower end | ---- | ---- | ---- | ---- | ---- | ---- |
| In Spring | ---- | ---- | ---- | ---- | 6.92 | 76 |

NOTE—In the above table, the asterisk (*) indicates that the temperatures were taken from the hatchery records for the date of the visit, in degrees Fahrenheit.

In the column for 1933, Oxygen Values, the results for Pond Surface were from samples secured at 3:30 P. M.; a sample taken at 9:30 P. M. yielded a result of 8.30 c. c, per Litre, or a per cent saturation of 137%, showing the effect of lowered oxygen level after sunset—compare with page 2 above.

Alterations will be observed in all of the physical and chemical factors investigated. The temperatures show a range from 3.2° C. to 23° C., which however, seemed to be entirely seasonal. The pond is supplied by spring-fed brooks, which explains the low values for spring and brook. There are also springs rising into the bottom of the pond.

The changes in the oxygen values are very striking. In the winter, the pond surface is covered by ice and snow, so that air can have no

contact and we have the low value of 70 per cent saturation, which agrees closely with the values for the spring in June.

The oxygen figures for the pond surface, and the hatchery water are very high. These high values are clearly associated with the photosynthetic activity of algae, quantities of which were being washed out over the hatchery dam, having been buoyed to the surface by the numerous bubbles of oxygen formed under the influence of the bright sunlight.

This high saturation of oxygen is not unfavorable in itself, for some experiments by Wiebe and McGavock have demonstrated that much greater concentrations have little or no effect on fish (Wiebe, A. H., and McGavock, A. M., page 267-274).

It is the high values for pH, or acidity measurement, which are probably the most significant. The high pH indicates a low value for acid, but a high one for alkalinity. The figure of 6.8 represents the normal acidity value for this water-system, as can be seen by reference to Table 4, for it is the value found in the hatchery during the winter (1931) and in June (1934) in the brooks and springs supplying the water, in the springs rising in the bottom of the pond, as well as those supplying the brook on the surface. This value was also secured in the water supply of the Superintendent's house close by, and is that found uniformly throughout Prince Edward Island in uncontaminated waters.

Samples of the surface water, taken from a boat throughout the length of the brook were uniformly 6.8 down to the level of the pond, where the still water was first reached, and there the figure jumped at once to 10.0. The first clumps of algae were also observed in the pond at this point, where the water became still, as the brook widened out into the pool. In the pond, the value of 6.8 was also found when samples were secured below the level of the intake pipe, five feet below the surface. A part of the pool is almost twelve feet deep, and this seems to indicate that uncontaminated spring water filled the bottom of the pool, and the up-welling water from these springs was mixing with the down-flowing impure surface water at the intake.

This increase of alkalinity, from 6.8 to 10.0 indicates a strongly dissociated alkali, that is a strongly basic or alkaline substance. This alkaline substance was not recovered from the pond water by analysis, but it is thought to be one of the nitrogenous bases produced by the decomposition of the algae. Some of these bases, namely those described as quaternary nitrogenous bases, are as strongly basic as potassium hydroxide. This alteration of pH becomes even more remarkable when it is considered that the pond contains about 1½ million gallons of water and there is a steady outflow of 150 gallons per minute, all of which outflow has enough base steadily added to maintain this high pH value.

The increase of the alkalinity of waters full of algae under the influence of photosynthesis is a well-known phenomenon, and some algae have a greater action than others. The usual explanation offered is

that the carbon dioxide (carbonic acid gas) is removed from the water by the plants under the action of sunlight to form their food materials, at the same time liberating the free oxygen which buoys up the algae, and gives the high oxygen values found in the pool. Certain soluble base-forming chemical compounds in the water containing carbon dioxide, tend to give some of it up, or become insoluble. It is this giving up of some portion of the acid part of these compounds which accounts for the increased alkalinity of the waters. In many natural waters the alkaline substance is calcium (lime), and under these conditions a pH of 9.0 is common (Wiebe, A. H., page 137; Irving, Laurence, and Becking, L. B., page 162; Smith, M. W., page 317; and Langlois, page 396). In the present case, the basic substance is not likely to be calcium for the pH is higher than calcium usually gives under these conditions, although calcium is a quite strongly basic substance. Furthermore, calcium is not poisonous, hence the base is most likely to be one of the more strongly dissociated bases, such as the alkalies, but possibly it is one of the nitrogenous bases, which as has been mentioned, are very poisonous. Some recent work (Howland, Ruth B., and Bernstein, Alan, page 276) has shown that similar nitrogenous substances are much more toxic in basic solutions than in acid solutions to living matter.

The evidence presented in this paper, unfortunately, is circumstantial rather than scientificially proven. Various causes exist for this situation, but the importance to aquiculturists, not only those in the hatcheries but those associated with lake work, and other phases of aquiculture, seemed to warrant the presentation of these observations, incomplete as they are, in the hope that if others have had similar difficulties, the tremendous economic losses involved in such cases can be obviated, and we shall be able to find the agents actually responsible.

As mentioned, the evidence for the conclusion that an alga has been responsible for a severe annual loss in a hatchery is largely circumstantial. Still the facts summarized below seem to make such a conclusion the logical one:

1. The loss occurs at a definite period each year.
2. The period is characterized by a certain temperature, i. e. 50° F.
3. The character of the water flowing into the hatchery is altered.
4. Large quantities of decaying algae are present.
5. The spring waters above the pool level, and in the pool below the hatchery intake level, have a pH value normal for the district.

It will be obvious that pollution of the waters exists. That this pollution may come from decaying algae seems to be probable because there are decaying algae present, and the fact that the loss is associated with a definite temperature indicates a biological factor. This must mean that the particular algae responsible grows in the early spring, in cold water, only to die when a lethal temperature is reached, produced by the early summer warming. There seems to be no evidence of an industrial pollution.

Grateful acknowlegment is made for permission to use the data here presented to the Fish Cultural Branch of the Department of Fisheries, in the person of the Director; and to the Biological Board of Canada, in the person of the Director of the Atlantic Biological Station, St. Andrews.

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## Discussion

Mr. Wolf (New York): I would like to ask Dr. M'Gonigle if he is sure that the parasites were in any way responsible for the mortality in the fish. I understand that in the New York City aquarium they had a good deal of trouble with acid which was injurious to the fish in the aquarium, and they corrected the situation by an apparatus which maintains the water in an alkaline state. But in making the water more suitable for the fish, they also made it more suitable to the parasites, so that they have had a good deal more trouble with the parasites on the fish since doing that.

Dr. M'Gonigle: The fish were very carefully examined for evidences of disease of all kinds that would produce parasites. The fact that the findings

were negative, of course, does not mean they were not there, but we were not able to discover any.

Dr. Emmeline Moore: Was there a definite bloom on the ponds each year preceding those times when you made the observations on the dissolved oxygen?

Dr. M'Gonigle: Unfortunately the hatcheries are located some distance from our own headquarters and I cannot be in constant attendance, so I could not answer that question. When I got there all I could see was this mass of floating dead algae; whether there was a bloom or not I do not know, but I think not.

Dr. Emmeline Moore: There must have been bloom, but I wondered whether it was noted whether the masses of algae were in spirals or in flocculent masses.

Dr. M'Gonigle: Flocculent masses.

Mr. Eugene Surber: Very recently workers in the botany department of the University of Minnesota, investigating the death of certain cattle which it was first believed had been killed by copper sulphate placed in certain lakes, found that the cattle had been killed by drinking the water of lakes which had very dense growths of such water-bloom algae as *Aphanicomenon, Microcystis* and *Anaboena*. These workers definitely proved that in the vicinity of these dense collections of water-bloom algae certain toxic substances were present in the water, and they showed that experimentally animals could be killed by the unknown toxic substances present in the water, produced by these algal growths.

Mr. Thaddeus Surber: Supplementing what my son has said in this regard, I may add that similar effects were discovered in poultry, sheep, hogs and cattle, but there is no evidence to show that during low water periods in these lakes it affected the wild fish that existed there in considerable numbers.

Mr. Rodd: Would Mr. M'Gonigle suggest any treatment that would overcome that unfavorable condition?

Dr. M'Gonigle: I suggest copper sulphate treatment prior to the period in which the outbreak is likely to occur. The water should be treated with algicidal doses which are not toxic to fish.

Mr. Charles O. Hayford: In Hackettstown we had a great deal of trouble with these various blooms, but during the last five years we have used a good deal of copper sulphate, which, if it is carefully administered, has no detrimental effect upon the fish. We have never used any fixed amount, because we find different amounts necessary at different times. If we do not keep that bloom under control, the first thing we know all our fish are up at the intake, fighting for air. By the use of copper sulphate we have been able to eliminate this trouble.

Dr. Davis: It might be of interest in this connection to point out that there are quite a number of cases on record where heavy mortalities have occurred among marine fish, ascribed to the presence of algae in the water. One instance I happen to remember was a serious mortality on the coast of Great Britain, ascribed to a species of flagellate. In all instances it was claimed that the mortality was due not to a reduction of oxygen in the water or anything of that sort, but to a definite toxic condition.

Dr. M'Gonigle: With regard to what Mr. Eugene Surber has said, may I point out that there are references in the literature to fish in lakes being killed under such circumstances.

# TROUT LAKES IN GASPÉ COUNTY

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The county of Gaspé is, of course, better known for its salmon streams than for its trout lakes, but the latter are not without interest for the sportsman, the naturalist and the fish-culturist. The streams of the county take their origin from the high mountains of the interior. These mountains, of which Table Top and Mt. Albert are two of the better known, form part of the Appalachian chain. Although the county is well supplied with lakes, small and large, their number is not to be compared with that of any part of the Laurentian chain known to the writer. The distribution of trout in the lakes of Gaspé is very irregular. It is by no means unusual to find lakes innocent of trout in Laurentian districts, but the proportion of such lakes to those containing trout is small. In Gaspé, on the other hand, the proportion of lakes devoid of trout, indeed fish of any kind, is much higher.

An example of this irregularity of distribution is found in the lakes of Table Top. Table Top plateau is approximately thirty square miles in area at an elevation of 4,000 feet, with many lakes and peaks of varying sizes and heights. The lakes of this plateau drain some to the Madeline and some to the Ste. Anne river. Some of the lakes of the Madeline system contain trout while none of these higher lakes of the Ste. Anne system have trout. All of the lakes of Table Top are inaccessible to migrating trout. What then is the explanation of trout in the lakes of one system and none at all in the other? This irregularity of distribution extends throughout the interior, indeed throughout the county. The Peninsula lakes, three in number, about fifteen miles from the village of Gaspé, and well known to the inhabitants, have never contained any fish until stocked with speckled trout fingerlings last fall (1933), although lakes in the near neighborhood have always, to the memory of man, contained trout. Another interesting fact is that in those lakes containing fish it is always *Salvelinus fontinalis* alone that is present. The fresh water of the county is poor in species, the lakes practically confined to trout; the rivers and creeks to salmon, trout, stickle-back and some members of the genus *Fundulus*. With only a few isolated exceptions it can be said that there are no purely fresh water fishes in Gaspé County.

Now although the sportsman would not be very interested in lakes devoid of fish, the naturalist might and, as for the fish culturist, such virgin—a much abused term—waters is a heaven sent gift that he may unequivocally demonstrate his usefulness and importance to the community. The hatchery at Gaspé, operated by this Department, although primarily for salmon, has since 1919 also served as a collection station of speckled trout eggs for the Department's other

establishments. With two exceptions these lakes were all devoid of fish of any kind, and in themselves are a further illustration of the irregular trout distribution in this county.

All of the lakes to be mentioned are in the near neighborhood of each other, except Grand Etang, and within fifteen miles of the village of Gaspé. None are accessible by road and all vary considerably in shape, size, depth of water and such other conditions as we have been able to ascertain. All of the soundings, as well as the lengths and breadths, were taken when the lakes had frozen over, permitting greater accuracy than could otherwise be expected.

McLaren Lake at its deepest part in the middle is 90 feet, with a considerable portion of its area being more than 50 feet. Ross Lake at its greatest depth is 70 feet, a considerable portion of it running more than 30 feet deep. Fourth Lake on the whole is more shallow, its greatest depth being 60 feet in the lower or eastern end, much of it running between 30 feet and 50 feet. Third Lake at its deepest point is about 40 feet, half its area being more than 20 feet deep. McLaren Lake, Ross Lake, and Third Lake are all fairly round, while Fourth Lake is decidedly oblong.

It is to be hoped that the observations on these lakes will be continued carefully in the future that a permanent technique of management may be evolved and some suggestions gathered to aid a policy of adequate exploitation of these and other lakes. The actual purpose of this paper is to gather and put on record as best we may the information already in hand, that it may be presented to this Society for discussion, and that a schedule of yearly observations may be drawn up.

The first lake used for the collection of eggs was Fourth Lake in 1919, the largest of the lakes used for this purpose. The greatest length was 5,331 feet and greatest breadth 2,395 feet. The greatest depth was sixty-five feet, with the greater part of the lake having a depth of over thirty feet. The bottom is largely composed of sandstone, and the lake appears to be rich in plankton. Apart from a few *Fundulus* sp. planted in 1932, there are no vertebrates other than trout and a few frogs present. The spotted newt, *Triturus viridescens,* common to all the other lakes has not been seen here. The food until 1932 consisted of plankton and insects. This lake was first stocked with trout (adult) many years ago, when an unnamed individual put in five river, i. e., sea trout. In 1919 hatchery officials stocked it with fry from sea trout for their own fishing. Reports of the fishing partially credited to the original stocking were so optimistic that in 1925 it was decided to attempt the collection of eggs.

This was the beginning of the regular trout egg collecting activities of the Gaspé Hatchery. The records kept of Fourth Lake are accurate but incomplete. The number of eggs obtained and the fry and fingerlings planted are all listed, but no count was kept of the numbers of fish seined or stripped. The largest number of eggs taken from this

lake was 670,000, in 1925, the first year of operation. There has been a steady and rapid decline in numbers ever since, to such an extent that in 1933 only 35,000 eggs were obtained. In this year we were liberating as many of the fish as possible without making the usual effort to take the eggs. The decline in the number of eggs from year to year was large enough to be obvious, and caused not by a reduction in the numbers of fish—as well as one can say in the absence of exact figures—but by a decline in the condition of the individual fish secured for spawning.

No doubt there was at the same time a decline in numbers of fish also, but it certainly was not nearly so striking as the poor condition of the fish. The fish are very poor specimens, big in the head and unbelievably thin and emaciated in the body. These ugly looking trout were observed in small numbers in the year collection operations were first started. Judging by the length of the fish and the size of the head, it is difficult not to postulate that the fish were adult before affected. Apparently healthy fingerlings are observed in the lake, and support this suggestion.

The adult fish taken from the spawning beds of this lake are referred to locally as slink, because of their poor condition. However, they are thin beyond the thinness of any salmon slink that the writers have ever seen. Many worms were observed in the gut and body cavity of these trout. A detailed study of these parasites was started in the summer of 1933, but unfortunately at that time the required slinks were few in number. Many had been removed the preceding fall, and the gates of the lake left open with the devout wish that the remainder would follow.

The fish examined during the summer were not affected to nearly the same extent as those of the preceding season, due either to the absence of the worst specimens, as suggested above, or because of the season. It is undoubtedly the case that the condition of the fish is aggravated by the development of the gonads. I do not wish to go into detail now with reference to the parasitization of these fish but will give one quotation from the report made: "It soon became evident that the gall bladder and the gut were the organs most infested with the parasites, the predominant parasites of the gall bladder being Trematoda, while in the gut, encysted or encapsuled Bothriocephalid Cestoda and Echinorrhynchid worms (Acanthocephala) predominated. In some cases very heavy infestation occurred and pathological manifestations were definite, though not necessarily lethal." It would appear from this that the parasitization may be considered as a contributing cause or even as a concomitant of the poor condition of these trout, but not the true cause.

If we can assume—and there is some evidence for this assumption—that only the adult stock are affected, that stocks do run down, and bear in mind that this particular stock was salt water in origin, then we have a plausible explanation of the present state of affairs at

Fourth Lake. The only practical effort to remedy this situation appears to be to remove as many of the affected stock as possible each fall when they are on the beds and easily captured, and to stock anew with fresh water stock. Stocking, as the list shows, has been going on since 1926, but until 1932 only fry were planted. In this year 8,000 fingerlings were planted and it may be that some amelioration will result this fall.

Ross Lake, within a half mile of Fourth Lake, is somewhat higher in elevation and considerably smaller in size but with some deeper water. It approaches the circular in shape, the greater diameter being less than a half mile. The visible portion of the bottom is of limestone as contrasted with the sandstone bottom of Fourth, and as a result the plankton is much richer than that of Fourth. There is an abundant supply of newts in the spring and fall of the year; apart from them and the trout the lake appears to be devoid of vertebrate life. There is a big proportion of shallow water, where the limestone gives it a very clear appearance. These shallows are well supplied with rooted vegetation, chiefly Potomogeton, with some Pipewort. The lake was first stocked in 1928 with 200 adult fish from Fourth Lake. It was again stocked in 1929 with the same number of adult fish from the same source, as well as with 5,000 fry. This is the extent of the stocking done. Until this time (1928) there were no fish in the lake. Eggs were first taken in 1930, when over 200,000 were collected. In 1931, 400,000; and in 1932 when only 415 females were used, over 850,000 eggs were taken. This averages just over 2,000 eggs per fish, which indicates that the average weight of the fish was over two pounds—a very good figure for such a small lake. Six and seven pound fish have been secured from here. Last fall the take had decreased to 600,000 eggs and it is to be feared that the peak has been passed.

It is to be noted that this lake was stocked with the trout from Fourth Lake which are sea trout in origin. And although the fish have spent some years, it is impossible to say how many generations, in fresh water, one cannot but fear that, to some extent at least, we have to look forward to the same sad experience here as resulted in the latter lake. Indeed, in the fall of 1933, fifteen slinks were observed: has it already started? And, if so, what of the stocking done elsewhere in the province with fry and fingerlings from these lakes?

There is at the moment in the office one specimen of a slink from a Laurentian lake. This raises an interesting point. In the inland lakes of this province one very seldom comes across trout that have died a natural death. They, like the rest of us, must come to an end, soon or late, yet we never see any in the act of dying or even weakening. At what age, I wonder, does a trout begin to feel that he is growing old, and when does he begin to show his age? One does not expect to see trout that have died naturally since they sink rapidly to the bottom, I presume, but surely we should see some signs of old age on some

occasion. Can it be that the sea trout and salmon are less secretive when their end approaches?

There are no inlets to Ross Lake and only a very small outflow. The fish spawn at three different places around the shore, in extremely shallow water, well under the overhanging banks of sphagnum moss and shrubbery, and show exasperating ingenuity in hiding and evading the net among the roots of cedar and other trees. Closer observations demonstrated that in all three places the eggs are laid in or very close to springs. If the total population of trout were permitted to lay their eggs in these locations the great number of eggs laid would in itself entail an enormous loss, both in eggs and resultant fry.

Pauline, Trail, and Paint Lakes are very small bodies of water, more deserving of the name pond than lake. All three were without fish until stocked by the hatchery. A record of the stocking as well as a map to show depths and lengths is included for each. Only Pauline Lake has been used to date. In the fall of 1933, 15 females were stripped and gave 25,000 eggs, nearly 1,700 eggs per fish. Rather surprising for such a small body of water. During the summer of 1934 a trout weighing six and a quarter pounds was taken from this lake.

McLaren Lake, just across the St. John River from the lakes just mentioned, is situated just over the top of a high hill. It is a rather unusual situation for a lake of this size. The maximum size is 1,724 feet and the breadth is 700 feet. This is a small lake if you will, but it has a maximum depth of 93 feet, and if we neglect the outer row of soundings the average depth is 42 feet, with a very limited area of shallow water. This is also a limestone lake, judging from the small proportion of the bottom that is visible. The limestone cannot be extensive in area or depth or else it would never hold the water of the lake. Much of the bottom, in shallow water at least, is covered with lumps of zoogloea, as large as one's fist, which appear to be similar to the gelatinous colonies of *Ophridium versatilie* so common in many of the Laurentian lakes of the province. There was no fish life in this lake or any vertebrates other than the spotted newt until the summer of 1932, when 2,000 yearlings and 6,500 fingerling speckled trout were planted. Both the yearlings and fingerlings were small for their age, having been raised in very cold spring water that seldom if ever exceeded 50 degrees F. during the hottest weather. The next year, that is, in 1933, 818 trout were seined from this lake and 70 females were stripped. The result was 60,000 eggs, i. e., 850 eggs per fish. This is quick results, and we look forward to a relatively large collection of eggs from McLaren's Lake in a few weeks' time.

Let us consider now Third Lake that drains into the York River as does Fourth Lake. The others, except Grand Etang, the next and last to be considered here, drain into the St. John. Third Lake is one of the larger lakes, with a length of 2,340 feet and a breadth of 1,882 feet. The greatest depth was 42 feet, and I do not think that I have

ever seen a lake with such uniform bottom contours. The lake is owned by The St. John Salmon Club who, in accordance with the custom of the country, do not fish salmon on Sundays. They have this trout lake that they may not be without sport on the Sabbath. They permit the taking of eggs by this Department in exchange for permanent and adequate stocking. This lake, unlike the others mentioned, has always contained trout, yet its outlet to the York River is as impossible for trout to ascend as are any of the others.

The table shows the number of eggs taken annually since 1929, the number of fish handled and the stocking made. It can be seen that the number of eggs varied a good deal from year to year; 1930 and 1931 were the two best years, when 600,000 and 400,000 eggs were collected. In both of these years all the eggs possible were taken in order to give the new stocking a good chance to succeed. We were endeavoring to build up a stock of larger individuals. Judging from the catches made this summer we have succeeded in increasing the size of the individuals. We will not know until this fall how the number of fish will compare with that of the original fish, although from the numbers handled and eggs taken in the years 1931, '32 and '33, it would appear that the stocking is effective and the size and number of fish are on the upgrade. The fluctuation in the number of eggs does not represent a correspondent fluctuation in the productivity of the lake, though it may be so regarded, I think, in the other lakes mentioned. The fish in Third Lake vary a good deal in the time of their spawning, some years several weeks later than others. Compared to the other lakes these fish are late spawners, and for this reason the lake is always the last one worked. And as the season advances, this means that in the interests of economy the full harvest is not always taken.

Grand Etang is about fifteen feet above sea level, and although we have no soundings or dimensions to offer, it is a safe assertion that the greater portion of its bottom is below sea level. This lake is readily accessible to trout from the sea. They come in each year to spawn and apart from this no fish, except stickle-backs and eels, are present. It is remarkable that of all the lakes mentioned Grand Etang, the only one accessible to trout from the sea, is without a permanent population of trout. And that of the others, only Third Lake should have trout indigenous to it. The most plausible solution is that in former years the relation of land to water was far different than at present, and that the trout indigenous to the highland lakes of the country are isolated descendants of a species that was once more widely distributed. The possibility of the accidental stocking of these waters by birds has this criticism to meet: namely, that the birds should have done a great deal better in the time at their disposal.

Thanks to the enterprise of the Gaspé staff, the Department has at its disposal a series of fine lakes for the collection of trout eggs. It has more. It has an opportunity to gather statistics that within a few

years' time should be of the greatest value. With management and care we should be able to tell with some accuracy the productivity in terms of eggs for all of these lakes. And if we take the trouble to secure each summer temperature, oxygen contents and other relevant readings, we should, some day, be able to estimate the productivity of other lakes elsewhere in the province, accepting these lakes in Gaspé, which are for the exclusive use of the hatchery service, as indices upon which our stocking policy will be based.

There is opportunity here for the study of many pressing problems: that of the fertilization of lakes for increased production, but only when we know much more of these lakes than we do at present; the introduction of some species of forage fish could well be undertaken here, though for my part I can see no good reason for the introduction of forage fish in lakes containing only trout. This species is, I believe, always at its best when alone, and produces enough eggs, fry and fingerlings to produce forage fish for the luckier or better equipped members of the species that eventually grow up. The trout at all stages of its existence feeds on plankton and insects and these, it seems to us, are the factors that set the limit of a lake's productivity. We might, when we have satisfactorily established the productivity of any

| YEAR | LAKE | FISH | | | EGGS OBTAINED | PLANTING |
|---|---|---|---|---|---|---|
| | | Male | | Female | | |
| 1925 | Fourth | — | | — | 670,000 | — |
| 1926 | Fourth | — | | — | 546,000 | 43,500 fry |
| 1927 | Fourth | — | | — | 440,000 | 12,000 fry |
| | Grand Etang | — | | — | 225,000 | — |
| 1928 | Fourth | — | | — | 570,000 | 39,800 fry |
| | Grand Etang | — | | — | 145,000 | — |
| | Ross Lake | — | | — | — | 200 adults |
| 1929 | Fourth | — | | — | 360,000 | — |
| | Grand Etang | — | | — | 105,000 | — |
| | Ross | — | | — | — | 200 adults and 5,300 fry |
| | Third | — | | — | 288,000 | — |
| 1930 | Fourth | — | | — | 427,000 | 30,000 fry |
| | Grand Etang | — | | — | 70,000 | — |
| | Ross | — | | — | 216,000 | — |
| | Third | — | | — | 600,000 | 15,000 fry |
| 1931 | Fourth | — | | — | 252,000 | — |
| | Grand Etang | — | | — | 122,000 | — |
| | Ross | 267 | | 324 | 415,000 | — |
| | Third | | Total: 2491 | | 416,000 | 10,000 fingerlings |
| | Pauline | — | | — | — | 14 adults |
| 1932 | Fourth | — | | — | 121,000 | 8,000 fingerlings |
| | Grand Etang | — | | — | 105,000 | — |
| | Ross | 397 | | 415 | 863,500 | — |
| | Third | | Total: 538 | | 215,000 | 900 yearlings |
| | Pauline | — | | — | — | 35 adults |
| | McLaren | — | | — | — | 2,000 yearlings & 6,500 fingerlings |
| | Trail | — | | — | — | 50 adults |
| | Paint | — | | — | — | 1,675 yearlings |
| 1933 | Fourth | — | | — | 35,000 | — |
| | Grand Etang | — | | — | 70,000 | — |
| | Ross | 359 | | 438 | 585,000 | — |
| | Third | | Total: 660 | | 286,000 | 2,800 fingerlings |
| | Pauline | | Total: 29 Used 15 females | | 26,000 | — |
| | McLaren | | Total: 818 Used 70 females | | 63,000 | — |

of these lakes, introduce a forage fish to see whether or not the plankton and insect life is utilized by the trout alone to the full extent. To determine this would necessitate several years and a careful choice of species.

The pressing problem that confronts us in the management of these lakes is the question of how many eggs we should take each year, what restocking we should do, and what we should do in the way of removing the older, i. e., the larger fish, since we have no other way of telling their age. At what size do the trout in our lakes reach the maximum as far as the productivity of eggs is concerned? Is it better to have one individual of four pounds, or several to make the same weight?

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# A METHOD OF PLANTING *OSMERUS MORDAX* MITCHILL ON A SMALL SCALE

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During the past two years several experiments have been conducted by the Piscicultural Branch of the Department of Colonization, Game and Fisheries of the Province of Quebec on the collection, transportation and planting of several stages of *Osmerus mordax* Mitchill.

The presence of this species landlocked in Lake Memphremagog is well known and one of the classical examples. A hatchery located at Magog at the foot of this lake enables large numbers of this species to be collected with ease at many of the stages of the life-cycle.

It is commonly accepted, especially for the small race such as found in the lake that the relatively small size, mild character and inoffensive habits coupled with the prolific breeding abilities of the species combine in this fish to form an excellent and abundant supply of living material which may be used for food by more predatory game species. In this connection most valuable of all is the production of large numbers of pelagic larvae.

The necessity for bolstering the available food in the majority of lakes inhabited by game species is generally only too obvious. Assistance is especially called for in lakes where stocking and protection have been combined to increase the game fish to a point close to if not surpassing saturation. In such lakes the forage species are most commonly found to be virtually extinct.

In the past (Kendall, '26) the common practice has been to transport and plant smelt either as eggs, very early fry or spawning adults. Each stage has presented some objectionable feature. The eggs, and fry raised from the eggs are minute and difficult to handle owing to their small size. Eggs, in particular, require the use of somewhat complicated techniques in order that fungus attacks may be avoided. Such fry as are used, being obtained from eggs present the same difficulties.

The transference of spawning adults from one location to another is to be considered a dangerous practice the possible reduction in numbers of the species subsequent to the removal of several generations may place the species in a precarious position.

Transportation of the pelagic larvae does not appear to have been employed and owing to the ease with which these stages can be collected near to the hatchery several trials were made.

In September, 1932, several thousand larvae ranging in length from

4 to 6 cm. were collected above the dam at the outlet of Lake Memphremagog where they gather in large numbers during August, September and October. These fish were held in troughs for several days and injured specimens culled out. It was found with these that any flow of water in the trough or any similar disturbance resulted in a mortality of 100%, and it became increasingly obvious that this stage is extremely delicate.

Similar larvae placed in troughs of standing water survived with only a very low mortality presumably only that of specimens injured in the course of the collection.

Continuing on this line it was found that the larvae could be transported successfully in the ordinary cans provided that the can was so completely filled with water that the splashing and disturbance of the water was reduced to a minimum. No attempts were made to lower the temperature of the cans and this was not found necessary.

Larvae handled in this fashion were brought to Montreal, a trip of four hours and survived astonishingly well. Following transference to tanks containing chemically treated city water all the specimens were lost in less than forty-eight hours.

In October of the same year transportation of much larger stages (6 to 10 cm. in length) was attempted with much success. These larvae, already commencing to lose their transparency were collected and shipped in containers as before to Breechers' Lake about seventy miles from the hatchery, and to Lyster Lake, about forty miles distant.

In the spring of 1934 smelt larvae were observed in large numbers in Lyster Lake testiying to the success of the experiment as the species was not present in the lake prior to this planting. In Breechers' Lake no smelt have been seen as yet.

In the latter case the larvae were held in cans for nearly two days before planting and although the mortality at the end of this period was slight the larvae may have been weakened to such an extent that their introduction later by mistake into a brook proved fatal.

In the spring of 1933 large numbers of eggs were collected on mats of Sphagnum moss and shipped to the St. Bernard Fish and Game Club.

Mats were prepared by backing moss with cheesecloth and nailing the whole to laths. These were placed on the bottom of cribs sunk in a brook where large numbers of mature adults had collected for spawning. Several of the adults seined from the brook and placed in the cribs would spawn and the eggs sinking to the bottom become fastened to the moss by their adhesive pedicels.

The first and last mats used were sent to the Zoological Department at McGill University and estimates of the numbers of eggs collected made and the course of events followed.

Calculated by volumetric method an average of 240,000 eggs was

collected on each 1,000 ccs. of moss. An average of 11% of the eggs collected was dead most probably in consequence of non-fertilization. Penetration of the eggs into the moss depended strikingly on the packing of the moss. On a densely packed mat penetration below the surface was practically nil and the number of eggs collected on this mat dropped considerably.

Development continually satisfactorily for nearly a week but the appearance of fungus which spread rapidly throughout the entire mass at this time killed off all the eggs. Applications of salt and of Scott's mercurochrome failed to check the growth of the fungus or to save the eggs.

It was apparent that had the mat been teased out the rapid spread of fungus would have been greatly impeded and culling out of infected material might have resulted in the saving of the majority of eggs. At the same time it is felt that the rotting of the moss which cannot endure a long sustained immersion in water had contributed markedly to the onset and rapid progression of the growth of the fungus. Owing to the lack of suitable aquatic plants at this time of the year, it is planned to employ in the future the finely meshed, hair-like aquatic roots of willows which may be collected near the hatchery.

At the present no information has been received as to the success of this trial planting of eggs.

From the data collected in these experiments it is obvious that the collection and transportation of advanced larvae is the most suitable both biologically and economically for the present situation in this Province where requests for the planting of the species have been so few that they fail to justify the incurring of any great expense in the form of apparatus or time on the part of the Piscicultural Service. The objections to handling adults, or eggs on a small scale have been mentioned above. Although early larvae were transported successfully it is felt that they are so delicate that their chances of surviving introduction into another water are small.

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# QUALITATIVE AND QUANTITATIVE ANALYSES OF FOODS FOR SALMONOIDS REARED ARTIFICIALLY

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At previous meetings of the Society recognized authorities in the fields of fish culture and animal nutrition have contributed findings which have helped materially to solve feeding problems confronting the fish culturist.

In most instances these discussions have dealt largely with the cost of foods in relation to the growth of the fish under observation, and especially with the results that may be expected when substitutes are used for the flesh of domestic animals.

The relative value of various species of freshly ground commercial or rough fishes, especially the wastes resulting from processing commercial species, does not seem to have been explored fully in the past.

In searching for foods which would be much less costly than fresh ground beef liver and other products, and which would be easily available, the writer conducted some extensive studies to determine the relative values of fresh commercial fisheries products. Some of the findings I am confident will be of interest to science and to the practical fish culturist as well.

Table 1 is of interest because most of the fish tabulated therein have proved to be good trout food when used in combination with fresh sheep liver and heart and salmon egg meal. According to these analyses, there is 25.83% more water in beef liver than in these thirteen different species of fish; 10.45% more protein; 2.9% more fat; .67% more minerals; 15.98% more nutrients, and 358 more calories per pound in beef liver than in fish. But it should be noted that there is recorded 40.54% refuse for the fish, representing bones, skin, and internal organs.

If the whole fish had been analyzed in each case, the average of these would have been larger than is indicated in this Table. This point is substantiated by the analysis for haddock wastes, minus the head. Analysis for dressed haddock corresponds very closely to that given for tomcod. If we combine the two analyses for dressed haddock and for haddock wastes (minus the head), we have the interesting picture as seen in Table 2. Here it is seen that while beef liver has 45.3% more water than haddock, this fish has, when its "wastes" minus the head are included with the analyses, 13.75% more protein than beef liver; beef liver has 4.55% more fat than haddock, and haddock has 10.15% more minerals than beef liver, and 17.55% more nutrients.

When preparing raw fish for trout food, the whole fish should be used. The viscera, pigmented epithelium of the skin, glands of the head and other internal organs and the nervous system, undoubtedly

TABLE 1—NUTRITIVE VALUES OF FISH, BEEF-LIVER AND HADDOCK WASTES

| Name of Fish, etc. | Per ct. of refuse; Bone, Viscera, Skin, etc. | Water | Protein | Fat | Minerals | Nutriments | Calories Per Pound |
|---|---|---|---|---|---|---|---|
| Alewife* | 49.5 | 37.5 | 9.7 | 2.8 | .8 | 13. | 285. |
| Bluefish** | 46.8 | 40.3 | 9.8 | .6 | .7 | 11.1 | 205. |
| Carp* | 37.1 | 48.4 | 12.9 | .7 | .9 | 14.5 | 270. |
| Cod** | 29.9 | 58.5 | 10.6 | .2 | .8 | 11.6 | 205. |
| Cusk** | 40.3 | 49. | 10.1 | .1 | .5 | 10.7 | 190. |
| Saltwater eel** | 20.2 | 57.2 | 14.6 | 7.2 | .8 | 22.6 | 575. |
| Hake** | 52.5 | 39.5 | 7.2 | .3 | .5 | 8. | 145. |
| Herring* | 46. | 37.3 | 10. | 5.9 | .8 | 16.4 | 435. |
| Spanish Mackerel* | 34.6 | 44.5 | 13.7 | 6.2 | 1. | 20.9 | 515. |
| Spanish Mackerel** | 24.4 | 51.4 | 15.8 | 7.2 | 1.2 | 24.2 | 595. |
| Mackerel** | 40.7 | 43.7 | 11.4 | 3.5 | .7 | 15.6 | 360. |
| Mullet | 57.9 | 31.5 | 8.1 | 2. | .5 | 10.6 | 235. |
| Mullet** | 49. | 38.2 | 9.8 | 2.4 | .6 | 12.8 | 285. |
| Pollock** | 28.5 | 54.3 | 15.5 | .6 | 1.1 | 17.2 | 315. |
| Tomcod* | 59.9 | 32.7 | 6.8 | .2 | .4 | 7.4 | 135. |
| Tomcod** | 51.4 | 39.6 | 8.2 | .3 | .5 | 9. | 165. |
| Per cent Average | 40.54 | 43.97 | 11.15 | 2.5 | .73 | 14.22 | 307. |
| Per cent Average of whole fish | 47.48 | 38.65 | 10.2 | 2.91 | .73 | 14.13 | 312.5 |
| Haddock Waste | | 9. | 62.5 | 1.5 | 22.5 | 86.5 | |
| Beef Liver | Carbohydrate 1.8 | 69.8 | 21.6 | 5.4 | 1.4 | 30.2 | 665. |

*Whole; **Dressed.

provide nutriments which, with the skeleton, if included in the analyses shown in Table 1, would have depicted a different picture. The bones and viscera certainly do contain nutrients of considerable value and importance.

TABLE 2.—COMPARATIVE FOOD VALUES OF DRESSED HADDOCK, HADDOCK WASTES AND BEEF LIVER

| Name of Matter Analyzed | Per ct. Refuse | Water | Protein | Fat | Minerals | Nutrients | Calories Per Pound |
|---|---|---|---|---|---|---|---|
| Haddock* | 51. | 40. | 8.2 | .2 | .6 | 9. | 160 |
| Haddock Wastes** | | 9. | 62.5 | 1.5 | 22.5 | 85.5 | |
| Total | 51. | 49. | 70.7 | 1.7 | 23.1 | 95.5 | |
| Average | | 24.5 | 35.35 | .85 | 11.55 | 47.75 | |
| Beef Liver | | 69.8 | 21.6 | 5.4 | 1.4 | 30.2 | |
| Difference*** | | 45.3 | 13.75 | 4.55 | 10.15 | 17.55 | |

*Dressed; **Haddock wastes minus head; ***45.3% more water in liver than in the average of dressed haddock and haddock wastes minus the head.

McCay, Titcomb, Cobb and Crowell (1930) experimented with a variety of foods which proved conclusively that trout do not grow and live on hay and other foods typical for cattle, e.g., alfalfa, linseed meal and cottonseed meal, although cottonseed meal can be used up to 45% in combination with raw meats. They also tried spleen preserved in 10% alcohol as a source of "raw meat" with "satisfactory" results. But I honestly doubt that trout fit for the table can be produced on such "food." A good trout food is an inexpensive substance easily procurable and perfectly suitable as human food which produces in trout rapid growth, vigorous health, splendid color, beautiful appearance, and a palatable fish for human consumption.

McCay, Bing and Dilley (*no date!*) report in a paper published by the Animal Nutrition Department of Cornell University, pp. 3-12, "That fresh raw meats contain a large amount of some unknown dietary factor which is essential for growth of trout." They "have termed this factor H." Moreover, "Factor H is thermolabile," and "is not identical with vitamins A, B, C, D, or E."

In this connection it may be noted that while salmon egg meal with raw meats, such as beef liver, sheep liver, sheep heart and/or assorted small fish (herrings, mackerels, and cods) produce better growth and better looking fish than any one of these raw meats alone or combined with each other, it cannot, under artificial conditions such as in a hatchery tank, raceway or pool, be fed indefinitely with a cooked food, such as canned herring, without the development in the trout of deficiency disease.

However, under natural conditions, when 5,500 brook trout and 2,160 rainbow trout four to five and one-half inches were placed in a screened brook located in a swampy country with an abundance of natural food (insects, crustaceans, worms), and with overhanging vegetation which provided plenty of shade, they could be fed on canned herring from May 31 to August 15 (1933) without any deleterious effects. Seemingly, they could have been fed on such canned food indefinitely. In fact, the fish grew from four to five and one-half inches to ten to fourteen inches during that time. The natural food present, evidently provided the essential "spark" so necessary for growth and well-being, but lacking in the canned herring. Furthermore, these fish received only about one-half as much artificial food during the time in question, as their fellows of the same age and initial size at the hatchery whence they came. When they were removed from this "wonder stream" and planted in other streams and in ponds, they were the most beautiful fish of their kind and age that any one in the state had ever seen. The length of the brook was about 1,500 feet; water flowage, 150 gallons per minute; temperature, 10-14° C. (50-57.2° F.).

It is perfectly evident, then, in order to attain all the desirable ends sought the thing for trout culturists to do is to develop an artificial food which resembles closely the natural food of trout. And these ***ends*** are not ***growth*** merely, but beauty and vigor in health as well. Such a food has a chemical set-up, qualitatively and quantitatively, which coincides with the optimum ideal natural structure possible of intussusception. See Birge (1929).

Lebour's beautiful works on "The food of young clupeoids," 1921, and "The importance of larval mollusca in the plankton," 1933, teach a very helpful lesson to those interested in fish culture and capable of profiting by such hints.

When one therefore considers the nature of food used by salmonids and clupeoids in their natural waters, one may be somewhat surprised by witnessing the kind of trout food used by trout culturists,

purposely or more or less fortuitously, foods which by chance were the most easily available and less costly, regardless of the physiological relationship between the consumer and the feed.

Thus, McCay, *et al* (1931), go to a great deal of trouble in concocting a variety of diets, which as trout foods—in the light of our knowledge concerning the natural diet of salmonids—one should know beforehand would yield unfavorable results. These workers, by analyses, found as we would suspect that haddock wastes contain 60-65% protein, 20-25% ash (chiefly tri-calcium phosphate), 1.5% oil and 8-10% water. This shows, as we have indicated above, when feeding the whole fish to trout one provides a higher percentage of nutrients by such foods than when feeding the dressed or filletted parts only. Unfortunately, the analysis does not include the viscera. The viscera, the head and the wastes referred to above should yield better results than the wastes alone.

Consideration has been given to stunting of trout without describing the conditions responsible (Titcomb, *et al.* 1929). It is claimed that "there is a real acceleration" in growth rate after a period of "stunting." The stunting, however, relates, it seems, to fish that had been kept "under a proper environment," but on a meager or, indeed, on no diet, during which time they show no increase in growth. Although "starved" they remained "in fair condition." Such stunting may not be stunting. For, in an instance when several thousands of one-inch fingerling brook trout were not fed for a period of weeks, due to too high temperature of the water, and relatively too little water available, St. Johnsbury, Vt., summer 1932, they attained only one-half to one-inch increase in growth for the remainder of the first season, after having been transferred to spring water (New Hampton, New Hampshire) with a temperature of about 8° C. (46.4° F.), and fed on beef liver three times a day for the rest of the summer and fall.

During the period, November 1932—November 1933, about 1,500 of these little fish were fed on the mixed diet of sheep liver and heart, assorted small fish and salmon egg meal on the 50-50 solid basis; but during the earlier part of this period the food consisted mostly of beef liver, until January, 1933, when it was augmented with the meal and twelve pounds beef testis, and ten pounds of beef blood. After this had been used up, the food was consistently the best used for other fish. By March 30, 1933, they were only one and one-half inches. (The food during the period January 23 to March 30, 1933, consisted of Ration No. 4, composed of equal parts of silver hake, beef liver and Balto with salmon egg meal on the 50-50 solid basis, in addition to beef testis and blood, mentioned above.) The growth increase during these 66 days with a temperature range of the water between 32.5° F. and 40.1° F. was 65%, with an average length of one and one-half inches.

Compared with different species of fish under identical conditions, the growth rate on this food is given in Table 3. By November 4, 1934, the great majority of these little brook trout remained much below legal size, e.g., three to four inches. Only two were five and seven inches, respectively. During the spring and summer, 1933, they were fed on beef liver, sheep liver and heart and assorted fish and salmon egg meal. Nevertheless, they remained small. This is a case of real stunting. Trout of the same species and age reared at New Hampton on the same diets were then six to ten inches in length, the majority nearer ten inches than six inches.

TABLE 3.—RELATIVE GROWTH IN PER CENT DURING 66 DAYS, JANUARY 23 TO MARCH 30, 1933. TEMP. 32½ TO 40.1° F. FOR EACH OF THE NINE SERIES

| Name of Species | Number Studied | Size March 30 in inches | Per ct. Increase | Food used |
|---|---|---|---|---|
| Chinook Salmon | 1,500 | 3½ | 71.4 | No. 4 |
| Landlocked Salmon | 1,500 | 2 | 57.0 | No. 4 |
| Stunted Brook Trout | 1,500 | 1½ | 65.0 | No. 4 |
| Small Rainbow | 1,500 | 2 | 68.6 | No. 4 |
| Small Lake Trout | 1,500 | 2½ | 70.2 | No. 4 |
| Normal Rainbow | 1,500 | 5 | 60.8 | No. 4 |
| Small Brook Trout | 1,500 | 3 | 60.6 | No. 4 |
| Select Rainbow | 400 | 8 | 76.0 | No. 4 |
| Normal Rainbow | 1,500 | 7 | 69.5 | No. 4 |

Average of 3 species of trout 2 to 3 inches equal 69.5 difference, 4.5
Average of all small trout 1½ to 3 inches equal 66.1 difference, 1.1
Average of trout and salmon under 4 inches equal 65.5 difference, .5
Average of all sizes except the "400" equal 65.4 difference, .4
Average of all sizes including the "400" equal 66.6 difference, 1.6

The percentage of growth was calculated in weight by grams. This shows that for the colder part of the season, these little stunted brook trout increased in weight 4.4% more than the smaller normal brook trout, and 8% more than the landlocked salmon, 6.4% less than the Chinook salmon, 5.2% less than the lake trout, and 3.7% less than the average of all the rainbow. Their growth was less by 1.6% of the average of all these species. Now, while the lake trout, the salmons, the rainbow and the brook trout of the other series increased rapidly in size with the increase of the temperature, the stunted brook trout remained much smaller, relatively, than the rest.

Temporarily starved fish under otherwise favorable conditions, such as volume of water flowage, space and temperature may not grow during such starving, but they may not be stunted. The smaller normal brook trout and rainbow were sorted out from amongst larger individuals. Their small size was due to "starving" having been reared under crowded conditions where the larger ones progressively got most of the food. In the case of the stunted individuals from Vermont, all the fish were very uniform in size, and, as indicated abnormally small for their age and opportunity of obtaining nutritive food.

Periodic growth inhibition through the use of either synthetic purified rations of starch, casein, and salt mixture with vitamin supplements and a low level of protein, may not lead to "stunting," as indicated by McCay, Dilley and Crowell (1929). Hence, the use of the word "stunting"

in such connections is misleading and should be substituted by the phrase "growth inhibition." Stunting is an induced physiological state that cannot be restored even under ideal environmental and food conditions. True stunting so modifies the potential proclivity for growth that the individual remains uniformly below the normal size of members of the same species of the same age, regardless of the food and other favorable environmental conditions to which it may have been restored.

A very fine trout food advocated by Hewitt (1931) is blue mussel. His method of having the mussels shucked through a process of boiling and then preserving the shucked mussel in salt may be augmented by either shucking after exposing the mussel to hot water long enough until the shell opens, and then remove it, to be shipped iced; such shucking would eliminate the boiling of the mussel with the attendant danger of losing some of its vitamins; or the mussel may be shipped unshucked to the hatchery, to be shucked there as needed. The mussels, as known, can live for many days in a cool place without sea water and without any deterioration. The shipments of fresh lots of newly collected mussels might then arrive from time to time at the hatchery as needed, with the minimum length of time since removed from the sea bottom or shore. Shipments can well be made in bushel baskets covered with sea-weeds.

Whole salmon eggs constitute an excellent trout food. Whole eggs should not be fed to fish under ten inches except as a part of other foods, being mixed with such in proportion not over 25 per cent. When fed alone, for some time, even to larger fish, the eggs tend to harden in the intestine of some individuals, causing death of the fish. It is better to feed eggs, when whole, about seven meals per week, alternating with other foods for the remaining fourteen meals in the week. It is quite possible to feed such eggs to smaller fish passing them through the cutter and then bind the "egg-soup" with salmon egg meal and raw meats. Such a combination, whether with sheep liver and heart and assorted small fish, or with any one of these meats and meal provides a most splendid dietary change of the highest order.

Einarsen and Royal (1929) surely pointed the way in the right direction, but it is clear that these authors failed to realize the underlying biological principle involved. None of the foods these authors specify, the "good" or the "bad" are alone satisfactory on the ground that no species of fish live on such in nature. This is the biological principle involved. The foods mentioned collectively would constitute a food nearer the normal than any group alone. In this connection it would not be amiss if one would give careful consideration to the rôle which aquatic algae (Tilden, 1929) play directly and indirectly in the economy of the piscatorial fauna in nature.

James (1928) makes an eloquent plea in favor of standarized food for hatchery reared fish; he concludes "that any new fish food resulting from such experiments must, if it is to receive a wide acceptance, possess in addition to proper dietary values, comparable to those of fresh meats,

a dependable source of supply for large quantities, and it must be available at a price not to exceed five or six cents per pound." The food I have described in another paper presented at this meeting costs about three cents per pound and is available in large quantities. In fact, since the fish grow twice as fast and are better looking and much healthier than liver-fed fish, the cost is actually less than one and one-half cents per pound.

Regardless of how closely a trout food may approach a normal or the natural food of such fish, and regardless of how inexpensive and abundant it may be, it is of paramount importance that the living conditions of the fish, the hatchery water be normal or natural too. This I have pointed out before (1933a) and Moore (1929) pointed out the need of chemical analysis of hatchery waters to determine the oxygen, carbon dioxide, the pH and alkalinity values from time to time. This is very important; it can be done at small cost.

If we would have healthy, rapidly growing trout, we must provide a good food and prevent oxygen deficiency due to overcrowding.

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# THE ECONOMIC VALUE OF TREATED SEWAGE EFFLUENT IN WILDLIFE CONSERVATION, WITH SPECIAL REFERENCE TO FISH AND WATERFOWL

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## Introduction

Happily it is no longer necessary to argue with the citizens concerning the importance and needs to the community of clean, sanitary streams for use in human economy; but, as the enlightened American knows, the great majority of our rivers with their tributaries have been rendered unsafe as sources of water supply for the human inhabitant and for livestock and wildlife as well. This grave danger to our social well-being gradually is being rectified by lifting the load of wastes from our waters through the erection, in centers of population, of offal or sewage treatment works. The sewage treatment works is therefore becoming a link of exceedingly great importance, not only in sanitation, but also in the economic life of America.

Heretofore, however, little thought has been given to the value of the by-products of sewage works. The main idea has been to clean the stream by collecting and treating the wastes of human activities, and removing such wastes from the natural waters. It has been partly recognized that the digested solids have economic value to agriculture; it is known that gases, depending on the nature of the sewage, may be collected at the plant to be used for illuminating, heating and power purposes; but the value of the purified liquid, the so-called finished effluent of the plant, as a source of basic food factors in aquiculture has not been as yet properly demonstrated in America.

In aquiculture, the purified sewage effluent may play an important part. Streams sometimes have too little organic matter in solution to stimulate distomaceous growth, microscopic plants upon which lower forms of animals live. Properly treated sewage effluent has this useful stimulant. It does not only abound in microscopic plants and animals, but it promotes their future development, and is therefore a very useful source of food for mollusks, insects, fish and waterfowl. Not until the pathogenic bacterial have been killed off in the "warfare" between them and the anaerobes in the Imhoff tanks or in similar compartments is sewage effluent fit for fish or waterfowl.

Fish and waterfowl live on the insect larvae in such water, but the waterfowl finds special, additional food in the plankton-full detritus along the riparian areas of streams thus inoculated. Moreover, higher algae, such as *Chara, Bactrachospermum,* and larger aquatic plants, *Vallisneria, Bidens beckii, Cabomba, Sagittaria, Utricularia, Potamoge-*

*ton, Elodea, Lemna, et al,* will receive valuable nutriments and thrive in such waters. These plants and others often harbor or are associated with smaller plants, algae of the lower orders, with which are also associated many varieties of unicellular animals and aquatic insect larvae. Fish and ducks find here a large source of food.

## Historical

The Urbana Champaign Sewage Treatment Works serves a population of 43,012 (1930 census), distributed over an area of 4,456 acres.

The water supply for the cities comes from wells and is of satisfactory quality after treatment for iron removal and further purification. Typical analysis of the water is shown in Table 1.

**TABLE 1.—TYPICAL ANALYSIS OF WATER SUPPLY OF CHAMPAIGN AND URBANA**

**Stated in Parts Per Million Before Filtering**

| Determinations Made | Parts per million | |
|---|---|---|
| Iron, Fe | 1.2 | |
| Manganese, Mn | 0.0 | |
| Silica, $SIO_2$ | 14.1 | |
| Nonvolatile | 1.8 | |
| Alumina, $Al_2O_3$ | 0.0 | |
| Calcium, Ca | 66.9 | |
| Magnesium, Mg | 31.4 | |
| Ammonia, $NH_4$ | 5.3 | |
| Sodium, Na | 34.8 | |
| Potassium, K | 4.1 | |
| Sulfate, $SO_4$ | 1.2 | |
| Nitrate, $NO_3$ | 1.4 | |
| Chloride, Cl | 4.0 | |
| Alkalinity | | |
| Phenolphthalein | 0. | |
| Methyl Orange | 376. | |
| Residue | 380. | |
| **Hypothetical Combinations** | **Parts per million** | **Grains per gallon** |
| Potassium Nitrate, $KNO_3$ | 2.3 | .13 |
| Potassium Chloride, KCl | 6.1 | .36 |
| Sodium Chloride, NaCl | 1.8 | .11 |
| Sodium Sulfate, $Na_2SO_4$ | 1.7 | .10 |
| Sodium Carbonate, $NA_2CO_3$ | 77.3 | 4.52 |
| Ammonium Carbonate, $(NH4)_2CO_3$ | 14.3 | .83 |
| Magnesium Carbonate, $MgCO_3$ | 108.7 | 6.34 |
| Calcium Carbonate, $CaCO_3$ | 167.0 | 9.75 |
| Iron Oxide, $Fe_2O_3$ | 1.7 | .10 |
| Silica, $SIO_2$ | 14.1 | .82 |
| Nonvolatile | 1.8 | .11 |
| Total | 396.8 | 23.17 |

The iron content of many samples analyzed has been near two parts per million. Complete iron removal after filtering operation.

The plant consists of eight essential treatment units: control laboratory, coarse screens, four Imhoff tanks, pumping station, sludge drying beds, trickling filters, final settling tank and lagoon, the latter of which is used as fish breeding and rearing pond.

The yearly average of crude sewage received for treatment over the past nine years is 1213,6 m.g.y.[1] or an average daily flow of 3.3 m.g.d.[2]

The crude sewage covering the ten year period has an average

[1]Million gallons yearly. [2]Million gallons daily.

B.O.D.[3] of 235 p.p.m.[4] The final effluent of the plant for the same period shows a B.O.D. of 19 p.p.m., or a 92% reduction from crude to plant effluent. The D.O.[5] average in the stream above the plant is 8.3 p.p.m., and below it is 6.8 p.p.m.; in the fish pond 5.2 p.p.m.; plant effluent 5.8 p.p.m. These figures are for over a period of five to ten years, pH[6] 7.7. The mean temperature average for the same period was 52.2° F. The yearly low and high temperature averages over this period were 5° F. below zero and 99° F. above zero, respectively.

BACTERIOLOGICAL ANALYSIS, JUNE 30, 1934

| | |
|---|---|
| Crude Sewage | |
| Plate Count | 851,000 per cc |
| *Bacillus coli* | 100,000 per cc |
| Anaerobic Spore Formers | 1,000 per cc |
| Imhoff Effluent | |
| Plate Count | 1,620,000 per cc |
| *B. coli* | 10,000 per cc |
| Anaerobic Spore Formers | 1,000 per cc |
| Final Effluent | |
| Plate Count | 8,400 per cc |
| *B. coli* | 1,000 per cc |
| Anaerobic Spore Formers | 1 per cc |

The effluent from the treatment works flows into the Salt Fork (dredged in 1908 and now known as Saline Drainage Ditch), a tributary of the Big Vermillion River in the Wabash River watershed. It has a drainage area above Urbana of 76 square miles. Outside of the stream valley, the drainage area is a relatively flat till plain of glacial origin, including moraines of the early Wisconsin glaciation. The stream valley is well defined with a variable stream bed, comprising mostly mud bottoms with occasional stretches of riffles where the bottom is sand and gravel. There are two artificial dams in the stream—one just east of Urbana, above the sewage works, and the other approximately 20 miles below the plant. The width of the stream bed is 20 to 40 feet, and the depth of water in dry seasons is a few inches to about 2 feet. The small tributary creeks in summer months are quite dry, with frequent pools of water. A reference to Table 2 gives analytical data associated with this stream.

TABLE 2.—SEVEN YEAR STUDY, DISSOLVED OXYGEN AND BIO-CHEMICAL OXYGEN DEMAND, SALINE DRAINAGE DITCH ABOVE AND BELOW SEWAGE TREATMENT WORKS, URBANA AND CHAMPAIGN SANITARY DISTRICT

| Year | Above Plant Outlet | | Swartz Bridge, 1.65 Mi. Below Outlet | | Lesse Bridge, 11.25 Mi. Below Outlet | |
|---|---|---|---|---|---|---|
| | D.O. | B.O.D. | D.O. | B.O.D. | D.O. | B.O.D. |
| 1926-27 | 6.9 | — | 6.5 | — | — | — |
| 1927-28 | 8.1 | 3.0 | 6.8 | 8 | — | — |
| 1928-29 | 8.1 | 3.0 | 6.8 | 8 | 8.0 | — |
| 1929-30 | 8.1 | 3.7 | 5.2 | 4.7 | — | — |
| 1930-31 | — | 4.2 | — | 4.4 | — | — |
| 1931-32 | 10.4 | 5.4 | 8.9 | 5.6 | — | — |
| 1932-33 | 8.2 | 7.5 | 7.9 | 16.1* | 18.25 | 5.6 |
| 1933-34 | 7.7 | 15.1 | 6.9 | 26.5* | 21.5 | — |

*The reduction plant located .75 miles below the Sewage Treatment Works passed the wash water from their cookers through a lagoon previous to 1933. Since then they passed it directly into the creek. This situation has been corrected by the State Board of Health during this fiscal year.

[3]Biochemical oxygen demand. [4]Parts per million. [5]Dissolved oxygen. [6]Hydrogen ion concentration.

Seemingly this stream with its useful food effluent from the lagoon could now be used satisfactorily in the breeding and rearing of ducks were the appropriate aquatic and semi-aquatic plants, including wild rice, cultivated along its course between Urbana and Danville.

## Lagoon Used as Fish Pond

In 1924, at the time of the completion of the plant, it was decided as a matter of economy to construct an inexpensive lagoon to receive the trickling filter effluent, using same as a final settling tank until such time when the district could finance the construction of a standard secondary unit. In October, November and December, 1928, four large carp (*Cyprinus carpio*), 50 yellow catfish (*Ameiurus natalis*), and 500 bullhead catfish (*A. melas*), were placed in the lagoon. In May and June, 1929, 39 two to three pound carp breeders (*C. carpio*), minnows (*Notropis*), 50 small mudcat (*Leptops olivaris*), 25 sunfish (*Lepomis pallidus*) and one grass pike (*Esox vermiculatus*), were planted in the lagoon. In September, 1930, the lagoon was planted with the following aquatic plants: Sago Pondweed (*Potamogeton perfoliatus*), Spatterdock (*Brasenia peltata*), Lotus (*Nelumbo lutea*), Muskgrass (*Chara*) and Wild Celery (*Vallisneria spiralis*). But we experienced difficulty in operation of the lagoon, due to the deposit of sludge which would show active septic condition during extraordinary hot weather, causing an effluent to leave the lagoon that was not as good as the filter effluent. For this reason a Dorr Traction Type Clarifier was placed in operation as a final settling unit in September, 1929, and the unfavorable condition in the lagoon has been entirely eliminated. This settling unit has sufficient area to give detention of about 1.2 hours on the basis of a 5 m.g.[1] flow. Prior to the installation of this unit, 9 dead fish had been recorded.

In December, 1931, the Dorr tank was shut down for repair. The water level in the lagoon became very low. Quite a number of large carp became stranded in shallow water. Six perished. Three specimens weighing an average of four and one-half pounds each were studied by students of Dr. Henry B. Ward of the University of Illinois. This study revealed no parasites of any kind in any parts of the fish.

In July, 1934, 510 mussels[2] were planted in the lagoon. The purpose of this planting was further to demonstrate the fitness of the lagoon as a rearing pool for marketable fish and game waterfowl. Mussels are highly sensitive to pollution. If they live in this water, the treated effluent of a sewage disposal plant, we are the more justified in our promotion of the use of treated sewage effluent in the economics of wildlife. If they do not live it is an indication that the water is

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[1]Million gallons.

[2]Consisting of the following species: *Amblema costata, Lampsilis ventricosa, L. siliquoidea, Lasmigona complanata, L. Costata Alasmidonta marginata, Proptera alata megaptera, Quadrula pustulosa, Tritigonia verrucosa, Pleurobema coccineum, Fusconaia flava, Striphitus rugosus, Ligumia iris noviboraci.*

not pure enough, but they may be expected to live in the subsequent lagoon units of a plant having a series of such.

This pond with an area of 25,000 square feet is a very interesting body of water. Carp (*Cyprinus carpio* Linneaus) do not only live in this water, but reproduce therein. The adult fish in this lagoon apparently measure twelve to eighteen inches. Schools of young carp were seen and about a dozen of the latter were taken for analysis of the contents of their alimentary canal.

**TABLE 3.—TO SHOW THE GENERAL APPEARANCE AND THE MICROSCOPIC BIOTA OF THE LAGOON**

A. General appearance: (a) Floating and suspended sludge in foam; (b) Large number of pond snail (*Physa gyringa* Say) floating in and on sludge on the top of the pool; (c) Schools of young carp (*Carpio carpio*) 2 to 2½ inches, seen feeding under mats of alga scum-floats and flocculent detritus. B. Microscopic biota, etc.

| Station | Date and Hour | T°C | Protophyta | Protozoa | Metazoa |
|---|---|---|---|---|---|
| 1<br>Inlet of Lagoon | 7/20/'34<br>10:00 a.m. | Air<br>34<br>$H_2O$<br>26 | *Oscillatoria prolifica*<br>*Orthosira oricalcea*<br>*Spirogyra crassa* +++ | *Amoeba proteus*<br>*Centrophris aculeata*<br>*Dinomonas vorax*<br>*Dendromonas virgaria*<br>*Pleuromonas jaculans*<br>*Lionotopsis anser*<br>*Lionotus wrzesniowskii*<br>*Frontonia leucas*<br>*Paramoecium caudatum*<br>*Paramoecium* sp.<br>*Spirostomum ambiguum*<br>*Stentor polymorphus*<br>*Euplotes charon*<br>*Zoethamnium adamsi* | Nematod larva<br>*Microdina paradoxa*<br>*Colurus grallator*<br>*Diplois daviesiae*<br>A gastrula<br>Physa gyrina + + + |
| 2<br>Bend of Lagoon | 10:15 a.m. | Air<br>34<br>$H_2O$<br>28.8 | *Stauroneis anceps*<br>*Chlorangium stentorinum* | *Monas* ++<br>*Bodo*<br>*Phacus brevicaudus*<br>*Dileptus gigas*<br>*Colpidium striatum*<br>*Euplotes charon*<br>*Oxytricha pellionella* | Nematod<br>Remains of *Daphnidae* |
| 3<br>Outlet | 9:00 a.m. | Air<br>34 | Shell of *Sirirella*<br>*Mastogloia smithii*<br>Rhoicosphenia *acuminatum* | *Monas*<br>*Metopus sigmoides* | Cyclops |
| | 7/21/'34<br>3:00 p.m. | $H_2O$<br>28 | *Spirogyra crassa*<br>*Oscillatoria prolifica*<br>*Stauroneis anceps*<br>*Surirella*<br>*Spirogyra crassa* (germinating) | *Peranema trichophorum*<br>*Pleuromonas jaculans*<br>*Heteromita ovata*<br>*Phacus brevicaudus*<br>*Coleps hirtus*<br>*Halteria grandinella*<br>*Holosticha vernalis*<br>*Vorticella campanula*<br>*Vorticella* cyst | |

The first third of the crescent-shaped lagoon had a light flocculent sludge bed about twelve to sixteen inches deep. From this sludge a large amount arose constantly to the surface and floated about, subsequently to sink, but again to rise to the surface, etc. The floating sludge consisted of decaying organic matter interspersed with a substantial microscopic biota, most of which were protozoa. *Vide Table 3.*

Large beds of filamentous algae bedecked the lagoon in several loci.

The algal beds were nearly 100% *Spirogyra crassa*. Only seven other species of unicellular algae were noted and only a few of each species.

Twenty-one species of protozoa were noted at the three stations established on the pond, eight macroscopic metazoa and nine species of algae. As indicated in Table 3, nearly twice as many species of protozoa were found per unit volume (3 cu. cm.) at Station 1 (inlet) as at Station 2 (middle of pond), and fourteen times the number of protozoa were collected per unit volume at the inlet as compared with that for the outlet, on July 20, 1934.

Six times more metazoa were noted at the inlet, Station 1, than at the outlet, Station 3, and twice as many at the "bend," Station 2, of the pond as at the outlet. The largest number of algae seemed to be at the outlet of the pool, though this might have been partly dependent on the "pull" of the water, which, of course, flowed toward the outlet. The wind action otherwise tended to collect the algal mats in the outer loop of the crescent.

The pool contained a large snail population of the species (*Physa gyrina* Say) which were especially abundant in the trickling filter unit of the plant. It was uniformly present all through the pool, floating at the surface and/or crawling on the flocculent top sludge of the bottom. This mollusk, undoubtedly, consumes a great deal of organic detritus of the lagoon and in that way is a useful scavenger. Like the carp, it is beneficial for such pools as this.

The ratio of microscopic oxygen consuming biota to that of oxygen producing was 34 to 7, or about 5 to 1.

Taking, however, the entire biota into consideration, the volume of oxygen producing organisms is far greater even though the piscatorial fauna be included.

The oxygen demand of the bottom itself, however, undoubtedly was considerable (vide Table 4), which nevertheless was seemingly neutralized by the oxygen supply furnished by the filamentous algae (*Spirogyra et al*).

Judged by these facts, and by the additional important fact that fish reproduce in this pond, and the young live, grow and are happy, healthful creatures, the pond receiving the effluent from the Champaign-Urbana sewage treatment works has demonstrated that sewage works effluent will support fish life. The signficance of this fact is of real economic importance. It suggests the possibility in future years of making use of the final sewage effluent from properly managed sewerage works as a source of food supply in the rearing of certain species of food fish and waterfowl. Carp can live in water with oxygen as low as three in p.p.m. (Agersborg, 1929), but whether they can reproduce in such water is questionable. In this instance, with reference to the Champaign-Urbana treatment works, the final effluent has at least twice as much oxygen in p.p.m., as compared with the influent of the pool. Furthermore, some species of fish do reproduce in such water. Its pH ranges for the summer were 8.8 to 9.0 with a tempera-

ture range of 22° to 31° C. between 8 A. M. and 4 P. M. The chemical analysis of the water for the months of July and August, the most critical time of the year (Radebaugh, 1929, 1929a) is of importance, for it shows the type of sewage-strength which may be converted into water pure enough to support the normal life of important economic biota. The additional cost to a sewage works plant which is to make use of its effluent in the rearing of game fish and fowl is negligible; the gains attained by such fish and duck rearing units would materially reduce the operation cost of the plant as a whole.

Analysis of the microscopic biota of the lagoon shows: The protophyta are comparable to that of beta-Mesosaprobic water, or meadow-pond and/or meadow brook water. That a species of blue-green alga, *Oscillatoria prolifica,* a sewage organism, should be present is to be expected in water undergoing natural purification. It does not occur in any appreciable number, however. Indeed, it might have come directly from the Dorr Traction Tank, as it was found only at the inlet into the pool, Station 1. The same applies to the diatom *Orthosira orichalcea.* The other diatoms, Stations 2-3, may be found in any kind of water, even pure springs. The presence of *Metopus sigmoides,* at the outlet of the pool, is of interest. This species is a sewage organism, although it may be found in trout rearing pools having some sludge bottom accumulated from food and excreta wastes in connection with the rearing of trout. However, in this present instance, the sample was taken from sludge which arose periodically to the surface by the lifting force of gases, the results of decomposition at the bottom. As shown in Table 3 (Station No. 3), no other protozoa were found on July 20, with *Metopus* save a few Monas, primitive protista. This might therefore indicate that an occasional flushing of this pond bottom might not be amiss. The practical solution of this would be to have two additional ponds into which this final effluent would flow and in which the actual and final rearing of marketable fish would take place.

On July 21, 1934, at 3 P. M., a sample taken in the same manner, from floating sludge by the outlet, showed nine different species of protozoa and four algae (see Table 3, Station 3). No new species of algae were noted. Of the nine species of protozoa, all were different from those recorded on the previous day for this station and four were different from those recorded for the whole pond. But all fall in the so-called higher zone of beta-Mesosaprobic water.

The protozoa as shown in our tables are divisible into the following classes or groups. Systematically they come, of course, under one and the same phylum, but physiologically they are divisible according to their adaptive propensities, practically all of which belong to typical pond water having some organic waste bottom and/or waste in solution.

There were two species of rhizopoda (*Amoeba proteus* and *Centropyxis aculeata*); eight flagellates (*Dinomonas voraz, Pleuromonas jaculans, Peranema trichophorum, Dendromonas vingaria, Heteromita*

*ovata, Phacus brevicaudus, Bodo* and *Monas*), all of which may be found in meadow ponds containing mainly organic wastes in solution from vegetation. The ciliates were mainly of the order *Holotrichida, e. g., Coleps hirtus,* two species of paramoecium including *P. caudatum,* and *Frontonia leucas, Lionotopsis anser, Lionotus wrzesniowskii, Colpidium striatum* and *Dileptus gigas.* There were four species of the order *Heterotricha*: *Stentor polymorphus, Spirostomum ambiguum, Metopus sigmoides* and *Halteria grandinella.* There were three species of *hypotrichous ciliates, e. g., Euplotes charon, Holosticha vernalis,* and *Oxytricha pellionella* and only two species of *Peritrichae; Zoethamnium adamsi* and *Vorticella campanula.* Of these, *Paramoecium, Colpidium* and *Metopus* are sewage organisms of the first order, and the rest are intermediate in type. The number of each species per unit volume was much like that comparable to a trout rearing pool in constant operation. Hence, the water, from the biotic standpoint, must be considered good.

## Analysis of the Alimentary Content of Fish

These data show that young carp, reared in the effluent pool of the plant, live on the natural biota of the pool, which is comparable to that of clean streams or ponds.

**TABLE 4.—CONTENT OF ALIMENTARY CANAL OF 2½ INCH CARP (2 TO 3 WEEKS OLD), JULY 20, 1934**

**Specimen 1.**
**The detritus consists of:**
- **(1) a *Phacus brevicaudus***
- **(2) a rotifier (shell of)**
- **(3) Remains of *Cyclops***
- **(4) *Arcella vulgaris***
- **(5) Amorphous material**

**Specimen 2.**
- **(1) Chaetae of tubificid worms (*Rhizodrilus lacteus* Frank Smith)**
- **(2) Copepoda skeleton**
- **(3) Chaetae of Naidid worm, *Pristina longiseta,* var. leidyi**
- **(4) Filament of *Oscillatoria prolifica***
- **(5) Many chaetae of Tubificid worms, *e. g., Tubifex multisetosus***
- **(6) Skeleton of *Nitzschia linearis***
- **(7) Skeleton of *Vanheurckia rhomboides***
- **(8) Amorphous material**

In August, 1934, 3,000 carp ranging from four to seven inches long were removed from the Dorr Traction Clarifier and placed in the lagoon. It is surmised that during the extreme hot weather experienced between July 25 and August 18, the young carp left the lagoon (going into deeper water) and arrived in the Dorr Tank, where they seemed to thrive. The temperature of the air ranging for this period was 57° to 104° F.

## Discussion of Literature

In 1908 (Forbes et Richardson, 1920) claimed that streams render town wastes "harmless by decomposition and useful by converting them more or less directly into a food supply for fish." One of us, Agersborg (1929, 1933), and again Agersborg and Hatfield (1929), Agersborg and Downer (1931), have shown that a considerable num-

ber of fish are attracted by the wastes in streams and by the planktons of treated sewage effluent. In addition to the microscopic fauna and flora of purified sewage effluent there are masses of amorphous organic flocculent detritus which forms more or less a sludge bed sufficient to enrich the soil of the riparian aquatic flora. Such slight sludge formations over inundated lands at times of high water can only serve a useful purpose. To the waterfowl population it is of obvious benefit.

The basic food of fish is, of course, microscopic, and, back of it are water and more or less simple chemical compounds which in the presence of sunlight or/and through enzyme actions of diverse bacteria provide other compounds upon which animals live. The simplest protista, other than bacteria, the monads and their kin, are holosaprobic; that is, they live on organic matters in solution. Higher microscopic protozoa live upon them and on bacteria, and in turn these serve an important link in a long food chain until the so-called useful forms of life are reached. But many higher forms, such as ducks, fishes and insect larvae, live directly on bottom detritus with its microscopic inhabitants, which serve directly as a source of food only one step removed from man himself.

Despite claims perhaps to the contrary notwithstanding, the effluent of treated sewage as shown above has a real economic value With this in mind, we propose as an economic measure in stream and wildlife reclamation, the inclusion in the engineering design and construction of sewage treatment works a series of spawning, rearing, and holding fish ponds to receive the treated effluent from the final settling units.

We have already indicated the type of fish planted in the Urbana-Champaign lagoon during the years of 1928, 1929, and 1930. At the present time it is certain that catfish and carp are still in the lagoon. And, furthermore, the carp is perfectly at home in this environment, having demonstrated the suitability of this habitat by reproducing its kind.

A plant starting its operation is excellently described by Radebaugh (1925). Again in 1926, Radebaugh and Day follow the bacteriological activities of a sewage disposal plant, pointing out the interesting battle between pathogenic and non-pathogenic species which in a properly constructed plant results in a victory for the non-pathogenic types prior to the influent to the filter beds and final settling tanks. This fact is of vital importance in our proposed utilization plant for fish and waterfowl culture. As indicated above, *Bacillus coli* actually disappear entirely in the three hours' detention of the effluent in the 600 foot lagoon. At the inflow, July 20, there were 1,000 per cc; at the outflow, none.

Radebaugh (1929) shows that the treatment of sewage is much less expensive than is generally thought. In fact, the per capita cost per annum for the average plant is about 42c for operation with a total cost, including operation, bond interest, and retirement of $1.65 during the life of bond issue.

Hatfield (1929) queries: How much do clean streams cost? Our answer to this question, of course, is in agreement with Dr. Hatfield's answer. It might not be beside the point, however, to ask: How much do insanitary, polluted streams cost? If all the facts responsible for and relating to human ills were known, it might not surprise one much if many of them will be found to be directly traceable to polluted streams.

In an article by Th. Falck (1934) entitled, "The Construction of Sewage Fish Ponds as Relief Work," the author states some very pertinent facts covering German experiments in carp culture in sewage ponds. The author states that "good ponds are more profitable than the best farm land, the best land is not too good for the purpose of fish culture." That "one kilogram of carp contains 30 grams of nitrogen and 11.63 grams of phosphoric acid or a proportion of 2.58:1. About 100 to 120 kilograms of plankton are required to build up one kilogram of carp flesh. Fish ponds work over about 60 to 80 times the nitrogen and 40 to 100 times the phosphoric acid content of the fish themselves. A one-acre pond with 243 kilograms of fish will take care of the sewage of 202 persons per year. Sewage from this number of people contains 591 kilograms of nitrogen and 148 kilograms of phosphoric acid."

In his experiments the author used three ponds: 64,500, 59,000 and 43,000 square feet respectively. He placed in these ponds carp and eels. At first the oxygen consumers *Beggiatoa* and *Sphaerotilus* appeared in the influent channel, but disappeared after adding calcium carbonate. Bone was added to furnish the phosphorus. According to this author the sewage from about 2,000 persons can be handled by a one acre pond.

We would not agree with Falck (1934) to feed fish on human wastes. Even though partially treated sewage effluent can be used, it is not good economy to risk wastes only partly purified, from a mixed human population on fish which are to be used as human food. The pathogenic bacteria must be killed first. We must have fairly good assurance that pathogens will not reappear, having passed through fish as infiltrable viri. This is the danger one faces when starting the rearing of fish too near the source of the waste.

In this point of view we are supported by White, *et al* (1928), who point out:

> "Disease in animals is closely related to disease of the human family . . . . . there is a large group of diseases that are common to both human and animal population. Anything which contributes to human health in the nature of sanitation or hygiene, is also a factor in aiding the general health of our animal population. The converse is also true . . . . . a severe outbreak of anthrax occurred in the state of New Hampshire a few years ago, due entirely to the contamination of the White River from anthrax spores emanating from hides."

Similar infection has been reported from Saratoga Springs, N. Y.,

the water having been inoculated by cattle infected by anthrax. Still other cases are reported from the South, where the Mississippi overflows and in that way infects the plants upon which cattle feed.

"Tuberculosis is another infection which it is possible to transmit through water contamination. A very important experiment on the transmission of bovine tuberculosis by water was carried out at the Government Experiment Station at Bethesda, Md., by the late Dr. E. C. Schroeder. A number of young cattle known to be free from tuberculosis were placed in a pasture through which flowed a stream. Some few hundred yards above, in a pasture hidden from the cattle by a wood, were placed a few animals known to have bovine tuberculosis. The stream, which originally was clear, became turbid from the tramping and droppings of the cattle in the upper pasture. Bovine tuberculosis showed up in the animals in the lower herd in about four months. There is no doubt whatever that streams polluted with living tuberculosis of a bovine source present a health hazard to animals which may drink, or otherwise become contaminated with water from such sources. Creamery waste may contain live bovine tuberculosis organisms that are a health hazard when discharged into our streams.

"In an article presented by Dr. J. J. Hinman, Jr., Associate Professor of Sanitation of the University of Iowa, before the Laboratory Division, State Board of Health of Iowa, it is stated that 'It is the writer's belief that except under unusual conditions it is economically advisable to free animals from dependence on surface water for their drinking supply. Ground waters, properly developed, will remove most of the dangers, which exist even in rural areas and become more and more grave as the human and animal population increases. For best results, water should be equal in quality to that furnished mankind.'

"He further states, 'There can be little doubt that unpurified surface water in any well settled land is a menace to all live stock forced to drink the water.' It would seem that a campaign to awaken farmers and live stock men to these dangers might economically be well worth while."

In the light of the above discussion of White and others, one may justly wonder why Manchester, N. H. (and there are, no doubt, others in our country like it) allows the wastes from the slaughterhouse for T. B. cattle to be dumped directly into Merrimack River. Are there not farmers below Manchester who use this water for their livestock? How about the riparian dwellers other than animals? Is the problem of tuberculosis among animals and man more or less directly traceable to polluted waters? We believe it is far more than is realized at the present time.

We believe, and as one of us has pointed out very clearly (Radebaugh, 1933a), "any community can far less afford to pollute streams than to keep them clean." The saddest part of the whole problem is the fact that the great brunt of the effect of polluted waters is placed on the shoulders of those who are the least able to carry this burden, and who are only in part indirectly responsible for this social and economic waste.

## Suggested Species of Fish

A few suggested species of fish to be reared in sewage treatment ponds, provided all factors conform, are:

1. Top minnow (*Gambusia affinis*) used in mosquito eradication.
2. Mudcat (*Leptops olivaris*).
3. Yellow bullhead (*Ameirus natalis*).
4. Brown bullhead (*A. nebolosus*).
5. Black bullhead (*A. melas*).
6. Golden Shiner (*Abramis crysoleucas*).
7. Carp (*Cyprinus carpio*).

In this connection it is pertinent to point out that success in the rearing of fish in sewage works effluent will depend on the constancy of the chemical composition of the finished purified effluent. Wide variation in temperature and pH concentration, as well as per cent dissolved oxygen saturation and the fluctuating qualitative and quantitative bacterial load will be factors to reckon with and to guard against.

Only one species should be attempted in each situation, for, as Coker (1925) and Agersborg (1933) have pointed out, the pH value tends to be definite for the habitat of each species. And we may add, the food conditions, oxygen content, and temperature are other factors more or less specific for each species. Constancy or fluctuation in these factors are of variable importance in the sum-total ecology of each species (Agersborg, 1930, 1933). Moreover, it is easier and more economical to handle one species in each situation than many. It is suggested that the mean carbon dioxide and pH values and mean temperature of natural habitats of fish contemplated to be reared be studied and the proper species be introduced accordingly. For the purposes, as described in this paper, it is felt that biologically digested sewage rather than chemically digested more or less periodically (Mohlman, 1934), can better provide constancy of conditions suitable for the rearing of wildlife.

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## Discussion

Mr. Adams (Michigan): I have been very much interested in Mr. Radebaugh's presentation. His proposition raises a question that seems to me needs the serious consideration of our scientists and those who are versed in this matter of fish culture and the commercial value of fish, as well as, perhaps, esthetic considerations.

My conscience still bothers me a little bit over a letter I wrote to a man in the Upper Peninsula in reply to one he wrote to us a year ago. We have a small institutional treatment plant near Marquette, involving the complete treatment of sewage similar to that at Mr. Radebaugh's plant. This fisherman stated he had fished a number of years in the little creek which received the fully treated sewage of this institution, a tuberculosis sanatorium, and he claimed this year he had not got a strike; he had fished over this particular length of stream without success. Finally he came along to the place opposite this institutional plant, and just as fast as he could throw his hook into the water he got strikes and caught his limit in no time. He went home thinking about it; then he went back, and he found he was fishing right at the point where the finally treated effluent, clear as crystal, was entering this small creek. He went home, dumped out all his fish, and wrote the Conservation Department and asked them to clean up this property, that it was a mistake that the treated sewage should pass into this creek. My rejoinder to him was that he had made a serious mistake; that if he would not say anything to anybody I would not say anything to anybody; we would not let anyone in on his secret. I told him to keep that fishing place and go back there every year. When you are putting fish in waters which are in close proximity to the treatment plant, if there is anything wrong with that from any point of view it is really a job for this Society to find that out. Now that labor is readily available we might very well in a number of places go into projects for the development of actual commercial values from this tremendous body of what would otherwise be waste water.

Dr. Emmeline Moore: I suppose it is one thing to eat fish out of a running stream into which treated effluent passes and quite another thing to eat fish out of your lagoon. Did anybody test the edibility of the fish in that lagoon?

Dr. Radebaugh: There is practically no danger from contamination after your waters have gone through a modern sewage treatment plant, because the pathogenic bacteria are destroyed in the process. Of course if you have just a pond such as we have, not such as the ponds we propose, I would say your question would be to the point. In Germany they raise carp in sewage waters; then after they attain a weight of about four pounds they put them through a series of treatments before they go to the market. I feel that the waters from a sewage treatment plant are free from any contaminating agencies, but I do not believe I would recommend to my people, in the lagoon we have, which is a very small body of water, the use of the fish for edible purposes.

Mr. Markus: At Rochester, New York, a year ago, as referred to in Needham's paper at the last meeting of the American Fisheries Society, we needed fertilizer; we had no money, so we used dried sludge from the disposal plant, and it worked. Necessity, you see, is the mother of invention, and that was the case here. This year I used it as fertilizer for all my bass ponds in equal amounts to cow manure, and I cannot see any difference, so far as fertilization of the pond is concerned, between the dried sludge and the cow manure.

# OBSERVATIONS ON THE EFFECTS OF DAMS ON LAKES AND STREAMS

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During the past five years a survey of the fishing conditions in the waters of the Province of Quebec has been conducted by the Piscicultural Service of the Department of Colonization, Game and Fisheries and the writer has been privileged in visiting a large number of lakes and streams which have been dammed in the past and some few lakes still in the natural state.

The part played by dams in preventing the migration of desirable species is well known. On the other hand, the fate of the waters which have been backed up has not been studied in the broader aspects of their physiographical nature, or of the mechanical alterations such as might have effect upon the game and forage species of fish, though in visiting many such waters a change from the natural condition is strikingly obvious.

Accordingly it is here attempted to reconstruct from data collected during recent visits to many lakes dammed a long time ago, up to seventy years, and others dammed within ten years, some concept of the changes which have taken place and an interpretation of the factors causal to these changes.

The most striking feature of a dammed body of water is the amount of dead wood present both in the water and around the shore. The amount varies with the extent of the area flooded and consequently is equally dependent upon the amount of elevation of the waters and the slope of the shore. Typically steep shores, a feature of our deep water lakes, are least affected as seen in the numerous Laurentian Lakes, while the more gently-sloping shores of the southern Appalachian waters suffer most severely.

In lakes where the level has been raised recently (Lake Aylmer, Lake St. Francis) it is found that there are two major consequences of the presence of such wood. These depend upon the degree of exposure of the locality to the mechanical actions of waves and the wind.

In exposed localities, the battering together of fallen timber breaks off the smaller pieces and fragments them, leaving only the cleanly skinned larger portions. The presence of these smaller fragments is a feature of the shore line of the majority of lakes. The larger timber remains for a long time, forty years at least (Lac de Montigny, Labelle Co.). This wood, three to twenty feet long and from four to twelve inches in diameter, exerts a scouring action at the water line under the influence of the waves and cleans away the softer bottom down to the hardpan. In consequence a sterile bottom such as may be seen at Lake Aylmer is produced and may extend out a hundred feet or more as an expanse in which life is restricted to a minimum of the hardiest rooted

plants, and generally of only a few transient species of fish (*L. cornutus* being most commonly found).

In sheltered bays and around the edges of small lakes where the above mechanical actions are limited the timber is less fragmented and serves as a trap for silt and detritus, which combined with the decay of some of the original terrestrial material provides a soft substratum, forming the basis for the development of swamps up to one hundred feet wide and more, duplicating the ecological conditions of the border of a typical pond. This is especially well seen in the broad swamps of Brompton Lake (Sherbrooke Co.), Spider Lake (Frontenac Co.), etc.

Since the tributary streams most frequently enter a lake at such sheltered localities, it is most common to find that there is a development of swamp reaching into the stream. This swamp is found to trap the sediment carried by the water of the stream and rapidly develops until it may block off the stream mouth and prevent the entry of any water into the lake other than by filtering through the swamp. This is a most common feature of our lakes, though found more in the Appalachian area, where the streams exhibit as a general rule a complete development of all typical phases.

The possible influence this may have on species utilizing the brooks for spawning purposes may be illustrated in observations made on the spawning of *L. corporalis* Mitchill at Brome Lake. This species enters all but two of the brooks running into the lake. In both exceptions the mouth of the brook is occluded in the fashion described by a dense growth of swamp. This undoubtedly acts as a weir against the entry of spawning fish. It is here suggested that in the fall when such developments of swamp are at a maximum the running of *S. fontinalis* Mitchill into many occluded brooks is prevented and materially reduces the most suitable spawning localities in many lakes.

In the Laurentian area the fry of *S. fontinalis* are found crowding the brooks close to the margin of the lakes. This has been seen at Lac Saugay and Lac Smith, Labelle Co., where fry abounded in the lower sections of the many small spring-fed trickles running into these lakes. In streams of large size the high velocities attained by the flood waters seem capable of sweeping away accumulating materials which would serve for swamp development. This is not a feature of the small brooks and as remarked at Lac de Montigny (Labelle Co.) the smaller brooks which formerly ran cleanly into the lake are now excluded from direct connection and no fry were present, although the lake is well stocked with trout.

The above few observations are presented in the hopes of offering some slight stimulus to the development of an appreciation of the factors other than hydro-physical and chemical involved in the course of events subsequent to the damming of a lake, and it is hoped that some realization will develop of the presence of physiographical and mechanical elements which must be taken into account as being as equally important as the former.

## Discussion

Dr. Huntsman (Ontario): I should like to ask Mr. Richardson how long a period elapsed after the removal of the dam to give a real test as to the possibility of returns to the original condition? I should also be interested to learn whether in any case there was an increase in the numbers of the better fish within a short time after the damage as compared with the later period.

Mr. Richardson: I am sorry I cannot answer your second question; I am a little bit too young for that. I have been visiting these lakes for the past five summers, and I have had to inquire from various people as to when the dams were installed. Where a dam is installed with the intention of logging off the surrounding land there is a terrific amount of erosion at the time and immediately after they cut the trees, and the lake is just full of silt. In many cases it is difficult to obtain any information as to the original condition with respect to fish life.

With regard to increase in the numbers of fish, in two cases brooks were dammed for the purpose of creating a pool for trout. In one case it was a complete success, except that the man lost his dam after the third year; in the other case it did not do any good at all.

Dr. Wiebe: I would like to ask the speaker, or anybody else, how much timber can be left in a lake before it becomes destructive or detrimental to the existence of fish life. A club in Texas has a lake ninety-five acres in extent, with water varying from fifteen to forty feet in depth. Although it has been stocked again and again, it does not seem possible to maintain any fish in it. They put a dam across a timber covered ravine and the water arrived before they had a chance to remove the timber. At a depth of nineteen feet in this lake there is absolutely no oxygen, and there is a high $CO_2$ content even at the surface. Of course the lake has this additional disadvantage: it is absolutely cut off from the effects of the wind. Is this condition merely the result of lack of aeration? Can you have too much decaying timber in a lake?

Dr. Emmeline Moore: May I ask what the source of the water is in the artificial lake?

Dr. Wiebe: Running spring water. The soil around it is to a very large extent sterile, and there is apparently no contamination in the water. The content of inorganic nitrogen compounds is very low. In addition to that the water is very soft, but there is a lot of free $CO_2$ extending to the surface. The only thing I can see is that it is due to the decaying timber, aside, of course, from the lack of sufficient aeration.

The President: Is anyone prepared to answer Dr. Wiebe's question?

Mr. Denmead (Maryland): Reelfoot Lake, Tennessee, was formed by the breaking of the Mississippi into low land, around 1815. It is almost all hardwood stumps and trees, some of them projecting out of the water from ten to twenty feet. Reelfoot Lake is one of the best black bass waters we have in the United States.

Mr. Thaddeus Surber (Minnesota): In north central Minnesota we have a dam about twenty-five feet in height across the Mississippi River which backs water into a lake nine miles above. In that case none of the timber was cut off before the areas affected were flooded, and I believe that lake has more fish to

the cubic yard than any other body of water in the states. The species are wall-eyed pike, rainbows, largemouth bass and pickerel. The water is simply impassable except in the old river channel. Some of the trees are still standing, although this dam was built upwards of thirty years ago. Anyone who goes in there can obtain a maximum bag of fish in a limited time.

On another lake in the northern part of the state, a natural lake which was used for the storage of logs, the logs were brought down by a logging railroad and dumped into this lake over a period of months; they were left on the ice during the winter and in the summer were taken out and re-shipped by rail to the mill a good many miles below. For many years the only fish that existed in that body of water were perch, all our efforts to restock it with wall-eyed pike having ended in failure. Recently, however, there has been a change in the conditions and we are now producing some wall-eyed pike in that lake.

Mr. Faigenbaum (New York): I can cite several examples of timber lakes in New York state; the state's biological survey there has encountered many. I believe that timber is an important factor in a lake, but not necessarily a ruling factor. In Cranberry Lake the bottom is very heavily covered with timber, so much so that I lost a very valuable sampler and the oxygen determinations on the bottom are not as complete as they might be. That lake offers excellent fishing. If sufficient organic matter reaches the lake to consume the supply of oxygen with which the lake starts the period after the spring thermocline, the conditions in the lake will be poor, but if sufficient organic matter is not present to consume that oxygen, I should think that the timber would not be a ruling factor. It is a controlling factor in the sense that it does make it more possible for organic matter to exist in undue amounts.

Mr. Roach (Ohio): The lakes of Ohio for the most part are artificial, in many cases covering wooded or forested regions. There are a few of the lakes in which the trees reach above the water, thus affecting wind action on the water and decreasing the oxygen to a considerable extent. However, I do not believe the effect of decaying timber in the water is enough to decrease the oxygen supply. In one case in Ohio, Lake St. Mary's, the average depth of the lake is only about six feet, and oxygen is present in the water from top to bottom in fairly equal amounts. The bottom of the lake is covered with fine, sandy, wooded decayed material.

Mr. Markus: I would like to ask Dr. Wiebe if he knows the $O_2$ content of the spring water flowing into the lake he mentioned?

Dr. Wiebe: No, we do not. The spring is at the bottom of the lake. It would probably have no oxygen in it at all. The water is apt to be acid to begin with. Much of the water in that region would run around a pH of 6.8; of course the pH of the water of the lake under those conditions would go down as low as 6.1 and even 6. The big factor there is the absolute lack of aeration by the wind, especially during a summer such as we have been having.

The President: This is another problem that needs a great deal of study and investigation.

# PLANKTON DISTRIBUTION IN MANITOU AND BROME LAKES

Mrs. J. T. Phillips

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Plankton tows have been taken in several lakes, of which the most complete records to date are for Manitou and Brome. An examination of the materials from these two lakes reveals some interesting differences in distribution, not unexpected in waters of such diverse hydrographical conditions.

Of the many groups of plants and animals represented in the plankton only two orders have been considered in this paper. They are the crustacean arthropods known as the Cladocera, or water fleas, and, the Copepoda. Ecologically they include two groups, the littoral and limnetic forms.

## Open-water Forms

It is notable that of six species of Cladocera and eight of Copepoda described as limnetic, two Cladocera and six Copepoda occur in Manitou but not in Brome. Moreover, four of these occurred at a depth of 10 to 20 m. in Manitou. There are no depths of this extent in Brome and one can suppose that the occurrence of these forms is precluded by the shallowness and the resultant higher temperatures of the water. It seems to be that temperature is the most important factor in copepod distribution and it so appears here.

*Daphina pulex* is extremely common in Lake Manitou, but absent in Brome. The other common species of Daphina, *D. longispina,* has three distinct varieties, which displayed a very interesting relation to their surroundings. In Lake Manitou all three varieties were found, and their occurrence was definitely limited by the depth.

*D. longispina typica* was found in Manitou at all stations, never above 10 m. and most numerous between 15 m. and 20 m. below the thermocline. This variety was not found in Brome. *D. longispina mendotae* occurred in Manitou from 5 m. to 15 m., and was commonest at 5-10 m., where there was a temperature range of 19-12 C. It occurred in large numbers in Brome where the higher range of temperature was prevalent. *D. longispina galeata* occurred in Manitou at the surface, and in Brome at littoral stations (A.D.E.).

The Copepods which occur in Manitou only are *Diaptomus oregonensis, Cyclops viridis americanus, Cyclops albidus, C. modestus,* and *C. fimbriatus.* These might all be called limnetic forms. *C. modestus* occurred at only one station and was there confined to the deep levels, 10-18.5 m. (bottom sample). *C. viridis americanus* was of common occurrence in Manitou, between 10-20 m. In Brome one of the commonest types of the Cyclops is a littoral variety *C. viridis,* namely

*C. viridis brevispinosus.* Although *Diaptomous oregonensis* is an extremely widely distributed form, and shows itself in many places to be of common occurrence, it does not appear to occur in Brome Lake.

Other open-water forms common to both lakes include: *Holopedium gibberum,* one of the largest members of the plankton; surface to 10 m. in Manitou. *Bosmina longispina,* also in the upper layers in Manitou. And two species of *Epischura; E. nevadensis,* 5-10 m. in Manitou, and *E. lacustris,* the commonest form, at Brome. This species is averse to light but seeks warmth; it is, therefore, not surprising to find it in Brome and in the upper layers in Manitou.

The majority of the open-water forms occur in Manitou, and not in Brome. Of those common to both lakes, none of the deep-water forms of Manitou can be included.

Of the littoral forms, five of fourteen species occur in Brome only: These include *Diaphanosoma brachyurum,* and *D. leuchtenbergianum.* The latter numerous at all stations. *Daphina retrocurva* was extremely abundant in Brome. *Chydorous sphaericus,* a minute form and *Cyclops phaleratus,* said to be peculiar to "shallow lakes and stagnant ponds."

The remainder, with two exceptions, are present in both lakes. The exceptions are a cladoceran, *Polyphemus pediculus,* and a copepod, *Cyclops bicolor,* of infrequent occurrence in Manitou. Amongst the rest of the cladocerans, *Bosmina longirostris* is the commonest in Brome and rare in Manitou.

Among the Copepods, the most interesting are *Diaptomous minutus* and *Cyclops leuckarti. D. minutus* was found at all stations in Manitou, never below 15 m., and usually higher. It is the commonest species in Brome and the individuals are much larger than those of Manitou. *C. leuckarti* occurred at all stations in both lakes, but it showed no variation in form.

*Sida crystallina* whose distribution is given as lakes and ponds among the weeds, occurred in Manitou at all stations in the upper levels, whilst only one specimen was observed in the material from Brome. The prevailing wind at Brome is southwest and some littoral forms including *Diaphanosoma leuchtenbergianum, Daphina retrocurva, Chydomus sphaericus, Cyclops phaleratus* were observed at open-water stations.

The following species have been found in Lake Manitou, not all the species occurring at each station:

*Copepoda:*

1. Epischura lacustris.
2. Epischura nevadensis.
2a. (Epischura sp.—not corresponding to either 1 or 2).
3. Diaptomous oregonensis.
4. Diaptomous minutus.
5. Osphranticum labronectum—(one individual definitely found. Reoccurrence doubtful).

6. Cyclops bicolor.
7. Cyclops fimbriatus.
8. Cyclops leuckarti.
9. Cyclops albidus.
10a. Cyclops viridis americanus.
10b. Cyclops viridis brevispinosus.

*Cladocera:*

1. Sida crystallina.
2. Latonopsis occidentalis.
3. Daphina pulex.
4a. Daphina longispina typica.
4b. Daphina longispina mendotae.
4c. Daphina longispina galeata.
5. Bosmina longispina.
6. Bosmina longirostris.
7. Bosmina obtusirostris.
8. Holopedium gibberum.
9. Leptodora kindtii.
10. Polyphemus pediculus.

As a rule the Cladocera are more numerous within ten metres of the surface. Below this, the Copepoda are more numerous, and the water becomes species-poor as well as thinly populated for the Cladocera. *Daphina longispina* has the longest vertical range of the Cladocera. This species in one or all of its forms was found at every station. Among the Copepods, *Diaptomous minutus* was the most regularly occurring species.

# THE DOMINATING SPECIES OF AQUATIC PLANTS IN BROME LAKE AND LAKE MANITOU (PROVINCE OF QUEBEC)

MISS J. D. SPIER

*Dept. of Public Works, Game and Fisheries, Quebec*

It was decided to make a comparative study of aquatic vegetation in Brome Lake and in Lake Manitou, since the temperature readings and soundings from the two lakes showed that we were dealing in the former case with a warm shallow lake characterized by the presence of bass and pickerel, and in the latter with a deep cold one in which trout were plentiful. The observations on vegetation were made in the latter part of July and early August, 1930. A flourishing growth of aquatic plants was obvious by that time in Brome Lake, and the growth in Manitou was, in all probability, as active then as at any other season.

The general aspect of the country surrounding the two lakes differs widely. The greater part of the shore of Brome Lake is settled with country homes or farms, and of the shore line, only a part of the western side remains wooded at all densely. The six main creeks that feed the lake pass, in their lower stretches, through a mile or more of either cleared or swampy land, the latter sometimes lightly wooded, sometimes open. In July, the flow of water in these creeks was extremely sluggish. On the other hand, the shores of Lake Manitou are on the whole thickly wooded to the water's edge. The creeks that feed the lake are smaller and more numerous than the Brome Lake creeks. Several of the inlets drain marshes, but the majority descend more or less abruptly from the surrounding hills through cool, moist, heavily shaded woods.

## VEGETATION OF BROME LAKE AND ITS CREEKS

The four main creeks drain wide areas of swampy land. Near their mouths the minimum width of stream was 20 feet, and a good depth of water was maintained. However the growth of water plants was so vigorous that in one creek, at a short distance from the mouth, only a three foot passage in midstream was clear of weeds, and the two creeks at the southern end of the lake were choked from shore to shore with a rank growth of vegetation that made it practically impossible to push oars through the water. Only those parts of the creeks accessible by boat are dealt with.

The tangled mats of vegetation in the creeks were principally made up of five different species of flowering plants: *Bidens Beckii* Torr., water marigold; *Utricularia vulgaris* L var. *americana* Gray, common bladderwort; *Batrachium trichophyllum* Bosch, common white water crowfoot; *Myriophyllum spicatum* L, water milfoil; *Elodea canadensis* Michx., water weed. The last two species were the most

prominent ones. Elodea in particular grew most rankly, attaining great length, and practically filling some of the streams where it was matted with a profuse growth of green and blue-green algae. The surface of the most sluggish parts of the creeks was covered with duckweed (*Lemna minor* L).

The distribution of the principal weed-beds of the lake is dependent upon depth of water and direction of prevailing winds. The outline of the lake is such that the greater part of the shore line is exposed to the prevailing westerly and frequent southwesterly winds. The most sheltered regions are along the southern shore, and it was there that the most dense aquatic vegetation was found. Benoit Bay and Soljes Bay were carpeted by weeds from point to point. At a depth of four feet, *Potomogeton Robbinsii* Oakes (and other pond-weeds to a lesser extent) grew closely crowded together. In deeper water *Potamogeton amplifolius* Tuckerman was plentiful. Eel-grass, *Vallisneria spiralis,* and water milfoil were very abundant, and some water-weed (*Elodea canadensis* Michx) was found. In shallow water quillworts (*Isoetes echinospora* var. *Braunii*) grew thickly and water lobelia (*Lobelia Dortmanna* L) was conspicuous, particularly in the more sandy regions. A dense growth of Rivularia colonies (blue-green algae) covered the older leaves of all submerged plants, and masts of Spirogyra, Oedogonium, Zygnema, Nougeotia and other green algae were commonly found wound about weeds taken from the water.

The remaining part of the southern shore line was more or less continuously weedy, although distribution of the water plants was much sparser than in the above-mentioned sheltered bays. Potamogetons were the most prominent feature of the vegetation of these regions. Bur-reeds (Sparganium sp.), yellow and white pond lilies, horsetails and reeds were scattered along the southern shore in shallow water.

The northwest shore showed three small areas of aquatic vegetation. Two of these were in the shallow water of small sheltered bays. Quillworts, stoneworts (Nitella), water crowfoot, eel-grass, water milfoil, *Naias flexilis* and a little pipewort (*Eriocaulon septangulare*) grew thickly on the bottom. Along the swampy shores of these bays were pickerel weeds (*Pontederia cordata* L) and arrow-heads. The third area showed small isolated patches of Potamogeton in a region not sheltered from prevailing winds.

The outlet is at the northern tip of the lake. Eel-grass was plentiful in the lake near the outlet, and the adjacent parts of the eastern shore were quite weedy. A more or less continuous line of pond-weeds—principally *Potamogeton amplifolius* Tuckerman—extended one-third of the way down the eastern shore. The line of weeds lay parallel to, and at some distance from the shore, the plants being most concentrated in the vicinity of the outlet. The central part of the eastern shore was clear of conspicuous vegetation, while the southern end again showed a scattered growth of pond-weeds.

The sandy bars at the mouths of the creeks on this eastern shore were practically clear of vegetation. Only a very sparse growth of *Naias flexilis* and of Batrachospermum (an attached red alga) was found. This condition afforded a strong contrast to that noted at the creek mouths on the southern shore. There the sheltered water into which the inlets emptied was filled with weeds.

Brome Lake, then is fed with creeks that drain rich swampy land. In July, 1930, they supported a dense aquatic vegetation in their lower reaches, and the sheltered areas of the lake into which the creeks emptied on the southern shore were also filled with water plants. Roughly one-half of the whole shore line was weeded. On the sheltered southern shore, and in the small sheltered bays on the northwest shore, there were eighteen species of aquatic plants (excluding the pond-weeds) each of which was a conspicuous feature of the vegetation. The vegetation on the exposed eastern shore, while quite widely distributed, was limited in quantity, and principally made up of species of Potamogeton, which grew in fairly deep water. The greatest variety of species on this eastern shore was seen in Fisher's Bay, where there were six prominent species apart from the pond-weeds.

A marked feature of the vegetation was the prevalence of the blue-green alga Rivularia. The colonies were exceedingly numerous in practically all densely weeded areas, where they grow in masses, over the older leaves and stems of submerged plants.

It is suggested from an examination of an earlier map of the lake that a filling in process has occurred in an area of dense aquatic vegetation. The early map shows the point to the east of Soljes Bay cut off from the mainland by a passage of water and called Grass Island. At the date of inspection, no trace of this passage was found. The island evidently now forms part of the marshy mainland.

## Vegetation of Lake Manitou and its Creeks

In August, 1930, Lake Manitou presented a very different picture. The water vegetation of the lake and its creeks was very scanty. By far the greater part of the shore water was clear of vegetation. Stretches of clear sandy bottom showed only a few scattered pipeworts or lobelias and, apart from some green algae on submerged branches, the abruptly descending rocky shores were quite free of conspicuous vegetation. The regions of the lake that showed the most extensive and varied vegetation were at the few points where the shore was low-lying and swampy. The most common aquatic plants in these regions were the large yellow pond lily (*Nymphaea advena* Ait), small yellow pond lily (*Nymphaea microphylla* Pers), pipewort, (*Eriocaulon septangulare* With), water lobelia (*Lobelia Dortmanna* L), water arum (*Calla palustris* L), horsetails (*Equisetum hiemale* L), arrowheads (*Sagittaria latifolia* Willd ?), and *Sagittaria graminea* Michx.) and a few pond-weeds (*Potamogeton epihydrus* Raf ?).

Apparently none of these plants found growth conditions very favorable, for nowhere did any of them form thick or extensive weed beds.

The majority of creeks showed only shade dwelling liverworts and mosses growing on the rocks above water, and Fontinalis, the water moss in the streams. Along their banks grew mosses and *Lycopodium lucidulum* Michx., a club moss. The bog moss Sphagnum was found surrounding the lower reaches of several creeks. At the mouths of four creeks quite large masses of algae were present. They were mainly composed of three species of Spirogyra—one of which was identified as *Spirogyra longata* (Vauch) Kutzing. Associated with the Spirogyra was Mougeotia, Zygnema and occasional desmids—all green algae. Only in one creek were blue-green algae seen, and that a creek which drained a small lake rich in vegetation, Mud Lake.

From a general comparison between aquatic vegetation of Brome Lake and that of Lake Manitou, it was evident that:

1. *Density of vegetation and predominating plant species:*

The weeded areas of Lake Manitou showed nothing that approached in density the rank luxuriant growth present in the sheltered weed-beds of Brome Lake, where the mucky bottom over wide areas was covered by a solid mass of aquatic plants.

None of the most flourishing species of Brome Lake was found in Lake Manitou. Elodea, *Potamogeton Robbsinii,* water crowfoot and quillworts, which were all very prominent in Brome Lake vegetation were not seen in Lake Manitou.

The species that did occur in both lakes showed less vigorous growth in Manitou than in Brome. The arrow-heads, bur-reeds and yellow pond-lilies and lobelias were less flourishing in the northern lake. Pipewort assumed a position of greater importance in the vegetation of Manitou, only owing to the scarcity of other species.

Rivularia, a blue green alga, was common on submerged plants of Brome Lake. In addition, Oscillatoria was commonly observed, and masses of Anabaena were collected from sheltered areas on the western shore. At Manitou, blue green algae were only seen in small quantities in a creek that drained a muddy lake.

In the few specimens of plankton examined for plant life, the proportion of diatoms seemed higher in Manitou than in Brome samples. While this examination was most cursory, it suggests that further investigation on this point might prove of interest.

2. *Size, nature and vegetation of the creeks:*

The creeks entering Brome Lake are larger and fewer than the creeks of Manitou. They pass through cleared land, swamps and low woods before reaching the lake, while, on the whole, the smaller Manitou creeks descend more abruptly through cool, moist, heavily shaded woods. Along the banks of Manitou creeks are found plants typical of cool, moist woods—along the creek banks of Brome Lake are found cat-tails, swamp-maple, willow, alder, button-bush and other typical marshy shrubs. The big creeks of Brome are densely weeded

at the mouths and for some distance back from the lake, while the creeks of Manitou are free of vegetation.

It seems possible that the following course of events has led to the dense vegetation recorded in Brome Lake. Owing to the extensive clearing in the vicinity of the lake, small creeks have dried up, leaving only larger inlets. The water flow in these inlets is slowed up at the end of the summer as the creeks in their courses pass through much cleared land. This sluggish flow permits in time a dense accumulation of aquatic vegetation in the creek beds near the mouths. At the time of the spring floods, the vegetable debris is swept out into the lake, and if poured into sheltered bays, fills in the bottom with rich muck, composed of decaying vegetable matter. In sufficiently shallow and sheltered regions, this forms an excellent bed for subsequent aquatic growth.

Our findings are in accord with those of Persall (1929, 1932) in that *Naias flexilis Elodea canadensis,* higher proportions of blue green algae and of pond-weeds are characteristic of the silted Brome Lake.

## Literature Cited

Persall, W. H.

1929. Dynamic factors affecting aq. vegetation. Proc. Int. Cong. Plant Sciences. 1: 667-672.

1932. Phytoplankton in the English lakes II. Journ. Ecology 20: 241-262.

# APPENDIX

## AMERICAN FISHERIES SOCIETY

**Organized 1870**

**Certificate of Incorporation**

**We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:**

**1. That the name of the Society is the American Fisheries Society.**

**2. That the term for which it is organized is nine hundred and ninety-nine years.**

**3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:**

**(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.**

**(b) To hold meetings.**

**(c) To publish and distribute documents.**

**(d) To conduct lectures.**

**(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.**

**(f) To acquire and maintain a library.**

**(g) And, in general, to transact any business pertinent to a learned society.**

**4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.**

**Witness our hands and seals this 16th day of December, 1910.**

| | |
|---|---|
| **Seymour Bower** | **(Seal)** |
| **Theodore Gill** | **(Seal)** |
| **William E. Meehan** | **(Seal)** |
| **Theodore S. Palmer** | **(Seal)** |
| **Bertrand H. Roberts** | **(Seal)** |
| **Hugh M. Smith** | **(Seal)** |
| **Richard Sylvester** | **(Seal)** |

**Recorded April 16, 1911.**

# CONSTITUTION AND BY-LAWS

(As amended to date)

## ARTICLE I

### Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

## ARTICLE II

### Membership

*Active Members.*—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

*Club Members.*—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

*Libraries.*—Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) dollars per year.

*State Memberships.*—Any State, Provincial or Federal Department of the United States, Canada or Mexico may, upon application and the payment of one year's dues become a State member of this Society. The annual dues for State memberships shall be ten ($10.00) dollars per year.

*Life Memberships.*—Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members provided that no member shall be so transferred unless he shall make request for such transfer and shall have paid dues as an active member of the Society for at least twenty-five years.

*Patrons.*—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

*Honorary and Corresponding Members.*—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several States and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

*Election of Members Between Annual Meetings.*—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club memberships. A majority of such committee shall decide upon the acceptance of such applications.

*Voting.*—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

## ARTICLE III

### Funds

*Current Fund.*—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

*Permanent Fund.*—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

## ARTICLE IV

### Officers

The officers of this Society shall be a President and a Vice-President, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named, shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-Presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

*Duties of Officers.*—The President shall preside at the annual and all special

meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

## ARTICLE V

### Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

## ARTICLE VI

### Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers:
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-Presidents of Divisions.
   e. Standing Committees.
5. Committees appointed by the President:
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussions of same.
   (*Note*—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

## ARTICLE VII

### Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

## AMERICAN FISHERIES SOCIETY
## LIST OF MEMBERS
### (Showing Year of Election to Membership)

### HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

### PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15, Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif.
'15 Burpee and Letson, Ltd., South Bellingham, Wash.
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Clinch, C. G. & Co., Inc., 144 Davis St., San Francisco, Calif.

'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co. (C. W. Weld, Mgr.), 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3rd St., San Francisco, Calif.
'15 Hendry, C. J., Co., 46 Clay St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The (W. A. Barbour, Mgr.), 443 Mission St., San Francisco, Calif.
'15 Mattlage, Chas. F., Company, 335 Greenwich St., New York, N. Y.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Phillips Sheet and Tin Plate Co., Weirton, W. Va.
'15 Pope and Talbot, Foot of 3rd St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California (W. D. Rigdon, Mgr.), 50-60 Fremont St., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

## LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wisconsin.
'25 Bradford, W. A., 14 Wall St., New York, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'11 Cleveland, W. B., Burton, Ohio.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'10 Gardner, Mrs. Charles C., The Cliffs, Newport, R. I.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Altadena, Calif.
'28 Hall, W. A. Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd-Smith, Wilton, 63 Wall St., New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3rd St., Columbus, Ohio
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'08 Prince, Dr. E. E., Dominion Commissioner of Fisheries, Ottawa, Canada.
'10 Radcliffe, Lewis, 5600 32nd St., N. W., Washington, D. C.
'20 Robertson, Hon. James A., Skerryvore, Holmefield Ave., Clevely's Blackpool, England.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina.
'14 Vandergrift, S. H., 1728 New Hampshire Ave., Washington, D. C
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., University of Illinois, Urbana, Ill.
'13 Wisner, J. Nelson, Institute de Pesca del Uruguay, Punta del Esto, Uruguay.
'05 Wolters, Charles A., Oxford and Marvine Sts., Philadelphia, Pa.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

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## PART II. AUTHOR INDEX